AD-A033 856 BOEING AEROSPACE CO SEATTLE WASH F/G 9/2
COMPUTER AIDED FUNCTION-ALLOCATION EVALUATION SYSTEM (CAFES).(U)
MAR 76 R E EDWARDS, K S RENSHAW, M J HEALY N62269-75-C-0239
UNCLASSIFIED D180-19338-1 NL

1 OF 3
AD
A033856

PHASE V FINAL REPORT

Computer Aided Function-allocation Evaluation System

MARCH 1976

PREPARED UNDER CONTRACT
N62269-75-C-0239 New

FOR
THE NAVAL AIR DEVELOPMENT CENTER
WARMINSTER, PENNSYLVANIA 18974

BOEING AEROSPACE COMPANY • SEATTLE, WASHINGTON

FOREWORD

The Computer Aided Function-Allocation Evaluation System (CAFES) is being developed by The Boeing Aerospace Company under contract to the Naval Air Development Center (Warminster, Pa.). To date, five phases have been completed: Concept Formulation (Phase I); Function Allocation Model (FAM) and Data Management System (DMS) (Phase II); Workload Assessment Model (WAM) (Phase III); Computer-Aided Design (CAD) Model (Phase IV); and development of selected interfaces between CAFES and the Crewstation Geometry Evaluation (CGE) Model (Phase V). During Phase VI, major emphasis will be placed upon completion of all initial CAFES developments, transition of the CAFES software from a research and development status to a production level status, and delivery and installation of the CAFES submodels to the NADC computing facility at Warminster, Pa.

This report documents the results of Phase V work conducted under Naval Air Development Center Contract No. N62269-75-C-0239 (10 March 1975 through 10 March 1976). The Phase IV documents contained a summary of all CAFES developments through 31 December 1974. Therefore, this report will only cover CAFES developments that have transpired since the Phase IV Program.

The authors would like to express their appreciation for the contributions made by the following people:

1) CDR R. J. Wherry, Jr., Naval Air Development Center for valuable suggestions on human performance modeling in general and the contributions made by his Human Operator Simulator and the CUBITS panel space optimization concept in particular,

2) Mr. Christian Skriver as Naval Air Development Center technical monitor who provided valuable guidance, encouragement and contributions to initial conceptual developments throughout the project.

3) LCDR P. Chatelier who has continued to provide funding support, program guidance, and technical contributions.

Within The Boeing Company, the program was directed by Mr. W. J. Hebenstreit of the Aerospace Group's Crew Systems Organization. Special thanks are due to Dr. Gene Gardlin, Mr. Charles Geer, Mr. Donald Parks, and Mr. Donald Whitmore of the Crew Systems Organization for their valuable suggestions.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

TABLE OF CONTENTS (cont.)

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

This report documents Phase V accomplishments in a continuing program to develop the Computer-Aided Function Allocation and Evaluation System (CAFES). CAFES is a crew systems design support system based on human engineering methods, computer aids, human performance data, and a data management system. It is intended to support crew systems engineers in systems development from initial mission and requirements analysis through design, test, training and maintenance systems development, as well as in the definition of man-machine research needs.

The present report describes the CAFES developments that have transpired since the Phase IV Program. These developments included: (1) completion of the military specifications and standards data sets (MILSTAN) that are used for checking the compliance of crewstations against military specifications and standards applicable to two-place fixed-wing aircraft; (2) completion of a CAD/CGE Interface Module for the automatic transfer of crewstation geometry data from the Computer Aided Design Model to the Crewstation Geometry Evaluation Computer Program System; (3) an analysis of the current status and the development potential of the CGE Reach Basket Model; and (4) completion of a DMS/CGE Interface Module to provide for input, execution and output of Crewstation Geometry Evaluation data via the CAFES Data Management System. The Phase V document also includes a discussion of the preliminary design specification for a CONsole Space Optimization and Layout Evaluation (CONSOLE) Model, and the CAFES Phase VI program plan.

KEY WORDS

Computer Aided Design
Crewstation Geometry Evaluation
Crew Systems Design
Digital Simulation
Human Performance Modeling
Military Specifications and Standards Testing
Panel Space Optimization
System Development

1.0 INTRODUCTION

This report documents all work accomplished during the CAFES Phase V Program. The report is divided into nine major sections: (1) completion of the military specifications and military standards (MILSTAN) data set; (2) development of an interface module between the Computer Aided Design (CAD) Model and the Crewstation Geometry Evaluation Computer Program System (CGECPS); (3) analysis of the CGE Reach Basket Model; (4) development of an interface module between the Data Management System (DMS) and the CGECPS; (5) development of a preliminary design specification for a CONsole Space Optimization and Layout Evaluation (CONSOLE) Model; (6) plans for CAFES validation and implementation; (7) restructure of CAFES documentation; (8) integration plan for CAFES submodels; and (9) the CAFES Phase VI program plan. Since the entire Phase V report is contained within one volume, information relevant to both the user and the programmer is contained within each section dealing with software development. Additional detailed information concerning program documentation and sample problems is contained in the Appendices.

The first section deals with work that was performed to complete the military specifications and military standards (MILSTAN) data set. This data set is used for checking the compliance of crewstation configurations against military specifications and standards relevant to two-place fixed-wing aircraft. To complete the MILSTAN data set, vector geometry for 44 new analytic functions was coded and input to the previous MILSTAN data set. Then, the new MILSTAN data set was executed against the A-7E aircraft to verify the new tests and to recheck the original tests. An error in the Geometric Object Manipulation Program (GOMP) and several errors in the previously used A-7E and MILSTAN data sets were discovered and corrected. A description of these errors is included in the MILSTAN section along with recommendations for possible improvements to the GOMP program that would enhance both the efficiency of the crewstation compliance checking procedure and the readability of the MILSTAN test results. Finally, the MILSTAN section contains a detailed discussion of the procedures to be used when future revisions of the MILSTAN data set are required.

Section two contains a description of the interface module that was developed between the Computer Aided Design (CAD) Model and the Crewstation Geometry

Evaluation (CGE) computer program system. The CAD/CGE interface module was developed so that the flexibility of data input inherent in the CAD Model could be applied to selected programs within the CGE system. The CAD/CGE interface module provides a means of formatting CAD output geometry so that a crewstation design can be input directly to CGE for analysis of reach infeasibilities or to test for compliance with military specifications and standards. A description of user inputs, model outputs, CAD/CGE interface logic and data bank categories is contained in this section.

A review of the present status of the CGE Reach Basket Analysis program is contained in section three. The Reach Basket Analysis program was examined to obtain an estimate of the resources that would be required to complete the model. Particular emphasis is placed upon a reduction in the amount of core memory and in the amount of execution time required by the model. A discussion is also provided on the background and source of the Reach Basket Analysis program and the link-system tree structure that is used in the model.

The fourth section contains a description of the interface that was developed between the Data Management System (DMS) and the Crewstation Geometry Evaluation (CGE) computer program system. The DMS/CGE interface module was developed to allow the CGE user to employ DMS capabilities for inputting cockpit plane and control definitions, control shape data and task sequence data into the CGE system. This section contains a description of the execution and report commands that were incorporated under the CAFES executive as well as a set of A-7E data that was input to the DMS to demonstrate CGE input, execution and output via the CAFES DMS.

Section five describes a preliminary design specification for a CONsole Space Optimization and Layout Evaluation (CONSOLE) Model. The specification provides a broad outline of desired capabilities and a set of specific requirements for an initial conceptualization of the CONSOLE Model. The specification includes a description of the general requirements and objectives of the model, the concept of the model, and the input requirements, computing routines and outputs of the model.

Plans for CAFES validation and implementation are discussed in section six. The implementation plan deals with the CAFES delivery schedule, verification tests

to be performed at the NADC computing facility and the presentation of informal training to acquaint NADC personnel with the CAFES models. The validation plan describes requirements for the effective utilization of the CAFES programs at NADC.

Section seven contains a discussion of the continuing effort to modularize and integrate the CAFES documentation into a pair of separate self-contained volumes for each of the CAFES models. A preliminary organizational scheme for the final CAFES documentation is presented in this section.

A detailed plan for the integration of the CAFES models with the CGE and the Human Operator Simulator (HOS) is presented in section eight. Several potential data interfaces between the three computer programs are identified and discussed in this section.

Section nine contains a description of the CAFES Phase VI Program Plan. Major emphasis is placed upon software refinements and documentation in anticipation of routine production runs following delivery and installation at NADC. The following tasks are discussed in section nine: completion of submodel integration; completion of submodel efficiency improvements; completion of user interface improvements; completion of system documentation; completion of CAD Model developments; preparation of CAFES training material, development of configuration control system and procedures; and delivery and installation of CAFES to NADC.

2.0 COMPLETION OF MILITARY SPECIFICATIONS AND STANDARDS COMPLIANCE TESTS

Analytic functions (vector geometry and geometric tests) for comparing and evaluating crewstation configurations with respect to military specifications and standards were developed during Phase III of the Cockpit Geometry Evaluation (CGE) Program. Fourteen separate military specifications and standards were examined to determine which specific requirements would be applicable for an automated compliance checking routine. Computer tests for many of these specifications were designed and coded but CGE development was terminated before this task was completed. One objective of the CAFES Phase V Program was to complete the development of all analytic functions for checking crewstation configurations against military specifications and standards relevant to military aircraft cockpits.

All military specifications and standards applicable to two-place fixed-wing aircraft have been coded and input to the CGE program. Several tasks were involved in completing the analytic functions. First, all previously developed analytic functions were reviewed to determine if the existing functions required modification or if new geometric tests were required. The review indicated that all of the tests had been fully completed for eight of the fourteen specifications and standards (MS33573, MS33574, MS33575, MS33576, MIL-STD-1847lD, MIL-STD-411D, MIL-STD-850B, MIL-B-8584C). Of the six remaining specifications and standards, two did not contain testable requirements applicable to fixed-wing aircraft (MIL-STD-250C and MIL-H-46855) and four required development of additional analytic functions (MIL-STD-1333A, MIL-STD-203E, MIL-S-9479B, and MIL-STD-1472A).

A total of 44 new compliance tests were completed during Phase V. Then, a series of specification compliance tests for the A-7E aircraft were designed and executed to verify the new tests and to recheck the original tests. In conducting these tests, an error was discovered in the original CGE coding. This error has been corrected and the software tapes have been updated. The content and format of the output reports from the new specifications and standards compliance tests are consistent with the format used in the original CGE Program.

The following section contains documentation that describes how the

military specifications and military standards (MILSTAN) data set can be updated and how the vector geometry subroutines of the Geometric Object Manipulation Program (GOMP) can be used to perform military specifications and standards compliance checks. A discussion of the GOMP design philosophy as it applies to military specifications and standards checks is also included in this section.

2.1 Procedure for Revising MIL-STDS/MIL-SPECS Tests in the GOMP/MILSTAN Computer Program/Data Base System

The GOMP/MILSTAN Computer Program/Data Base System consists of a computer program, GOMP (Geometric Object Manipulation Program), and two data sets; (a) coded MIL-STDS/MIL-SPECS on a file which is referred to as MILSTAN in all applicable documents, and (b) the user's input geometry describing the aircraft crewstation being tested. The coded MIL-STDS/ MIL-SPECS in the MILSTAN data set are actually a sequence of coded instructions in a format which GOMP recognizes. A separate data set, in addition to MILSTAN, contains the user-supplied crewstation geometry which is to be compliance-tested versus the MIL-STDS/MIL-SPECS which are "coded into" MILSTAN. When this geometry data set and MILSTAN are supplied together as input to GOMP (Figure 1), the result is a computer-generated list of test results for the user-supplied geometry.

The geometry data set consists partly of simple coded instructions and partly of 3-space geometry data in a simple format which describes the user's crewstation design. The coded instructions are interspersed with the geometry data and are in a format similar to the MILSTAN coded instructions. However, the only purpose of the coded instructions in the geometry data set is to instruct GOMP to read and store the geometry data and organize it as required for compliance-testing via the coded MILSTAN instructions. The following discussion assumes a basic familiarity with the GOMP and the MILSTAN elements of the CGE Computer Program System.

2.1.1 The Geometry Data Set

Points, lines and planes can be read and stored, and segment boundaries (e.g., a plane segment with a polygonal boundary) can be indicated.

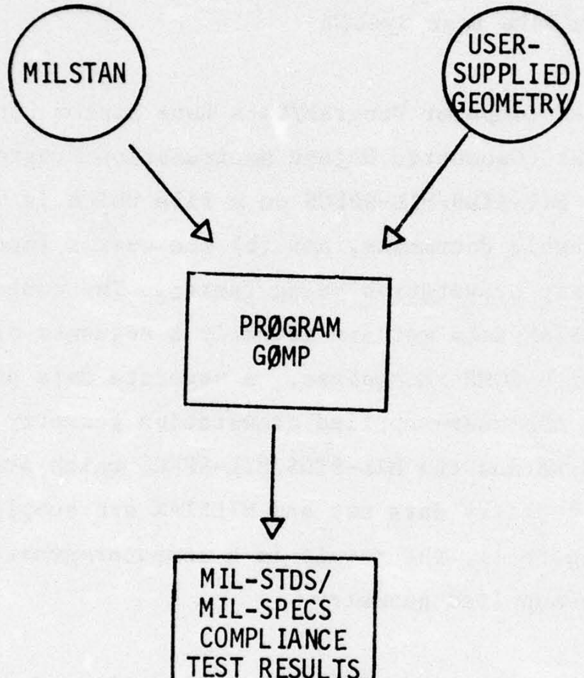

Figure 1. GOMP/MILSTAN Execution

This is done by reading in two points for a line or line segment, or from three to six points for a plane or plane segment. GOMP automatically computes, using the input points, a direction vector for each input line and a normal vector for each input plane. The format for these data consists of:

(a) an 8-character name, plus three coordinates for points,

(b) an 8-character name, plus two vertices (three coordinates per vertex) for lines, and

(c) a 30-character description followed by an 8-character name, followed by an integer from 3 to 6 indicating the number of vertices for planes. For each plane, this is followed by the coordinates for the vertices.

A fourth type of data is defined by the user with a geometry data set instruction which has been provided for the purpose of organizing groups of points, lines or planes into logical units. These logical units are called composites and they are used by the GOMP/MILSTAN system to conveniently access groups of geometric objects for compliance testing. These composites (or composite objects) are, in fact, one of the main features of the GOMP capability and are essential in most of the MIL-STDS/MIL-SPECS tests coded into MILSTAN.

The format for a composite definition in the geometry data set is very simple. An 8-character name for the composite is read in, followed by the names of the geometric objects to be included in the composite. The objects must have been read into storage prior to the execution of the composite definition instruction (see COMPOSE instruction, Reference 2) and the objects must all be of the same type, points, lines or planes. Objects which are named in the composite definition, but for which GOMP has received no data, will simply be omitted from the composite, with a printed message to inform the user.

A list of "standard names" for points, lines, planes and composites is presented in Reference 2 . New names are added to this list whenever the MILSTAN test instruction data set is expanded to include more MIL-STDS/ MIL-SPECS compliance tests. If a point, line or plane does not have one of these standard names, it must be included in a composite with a standard name via a composite definition instruction occurring in the user's geometry data set. Otherwise, it will not be referenced for use in any of the compliance tests during execution of GOMP and its inclusion in the geometry data set will, hence, be superfluous. A composite must have one of the standard composite names or it will not be referenced in any of the MILSTAN tests.

2.1.2 Geometric Storage Access

Program GOMP reads the geometry data (including the composite definitions) and then, on encountering the instruction "GO" at the end of the geometry data set, switches to the MILSTAN input file to begin executing the compliance tests. The compliance test instructions coded into MILSTAN are then executed sequentially as they occur in the MILSTAN data set. Each test instruction references geometric or composite objects by name, using the standard names referred to earlier.

The geometry referenced by the MILSTAN test instruction being executed is called from the applicable central geometric storage array (one for points, one for lines and one for planes) into a compact storage area known as a MILSTAN register. In central geometric storage, the geometric objects are referenced indirectly via table lookup on names (Figure 2). Whenever a composite is used in a test, the referencing of geometric objects in the composite is doubly indirect because the table lookup is performed to locate the composite by name. The objects within the composite are then referenced indirectly in a staged array process (Figure 3). Once the objects have been loaded into a MILSTAN register, however, they are referenced directly as needed in the calculations performed by GOMP to execute the current MILSTAN test instruction.

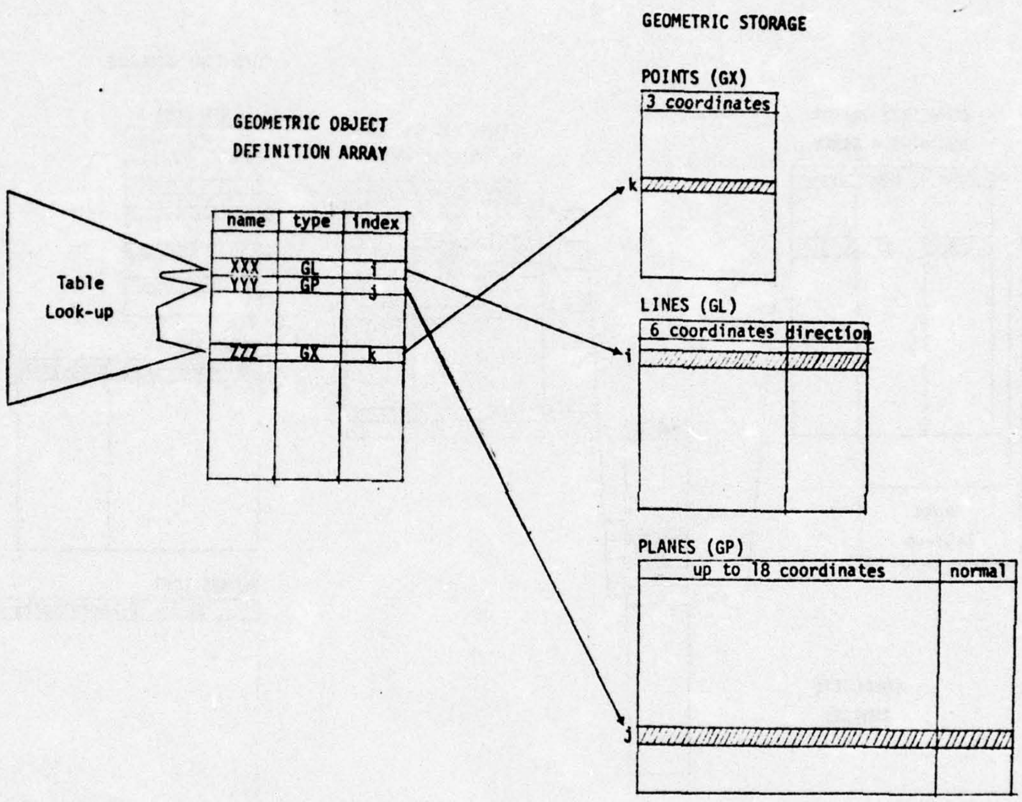

Figure 2. Geometric Storage Access by Geometric Object Name

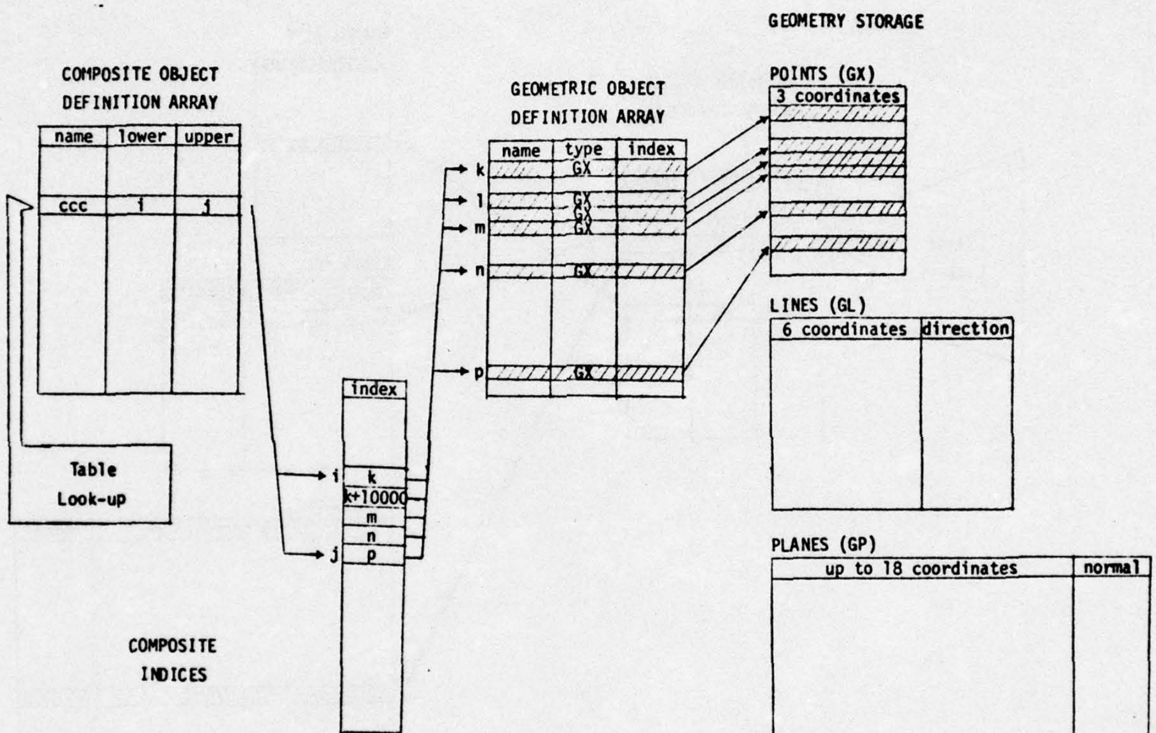

Figure 3. Geometric Storage Access by Composite Object Name

2.1.3 The MILSTAN Data Set

A MILSTAN test instruction consists of three basic types of instructions for GOMP which are executed in sequence, viz.: (a) OPERATE, (b) TEST, and (c) FORMAT. The first instruction, or instruction sequence, consists of one or more OPERATE instructions which call the appropriate geometry into a MILSTAN register and perform operations on the geometry to get numerical test results. Following one or more OPERATE instructions, one or more TEST instructions are used to perform the MIL-STDS/MIL-SPECS compliance test against some test criterion using the numerical results from the OPERATE instruction(s). Finally, one or more FORMAT instructions will cause the test results to be printed out in a specified format. The following examples show input data in card image format where all items, except for the output format, are left justified in a ten column field.

Example 1

The MS33574 test, "Design Eye Point must be 31.5 inches above Neutral Seat Reference Point", is performed with the following instructions to GOMP in the MILSTAN data set:

```
AND
OPERATE
DIST      ABOVE
NUTRLSRP  DEP       *
TEST
GE        31.437
AND
TEST
LE        31.563
FORMAT

DEP MUST BE 31.5 IN. ABOVE NUTRLSRP
*
PRT       SUCCESS   PASS      TOL
```

In this case, there is only one OPERATE instruction. It consists of the lines

```
OPERATE
DIST      ABOVE
NUTRLSRP  DEP      *
```

The "DIST ABOVE" line is interpreted as the distance of a point above a reference point. In this case, the distance of DEP (design eye point) above NUTRLSRP (neutral seat reference point) is to be found. The * indicates the end of the list of objects to be operated on. The operation is performed by subtracting the Z (vertical) coordinate of NUTRLSRP from that of DEP, where the "up" direction is that of increasing Z. Thus, distance above is positive or negative depending on whether DEP is above or below NUTRLSRP.

Two important points to note here are:

(a) GOMP assumes a certain coordinate system orientation, although the coordinate origin is determined entirely in the numerical data for the user's geometry. The orientation is: positive X is to the right of the crewstation, positive Y is forward, and positive Z is straight up.

(b) It is not specifically mentioned in the OPERATE instruction that NUTRLSRP and DEP are points. GOMP discovers this for itself after table look-up in the Geometric Object Definition Array (GODA) to find the locations of the geometric objects named NUTRLSRP and DEP in central geometric storage (see Figure 2).

Part of the information in GODA specifies the geometric type (GX for points, GL for lines, GP for points) of each object. This tells which storage array contains the numerical data for the object and which type of operation to perform. Although there is no DIST ABOVE operation for other than points, suppose the operation had been coded in MILSTAN as DIST FROM.

In this case, there are many possibilities provided by GOMP. If the objects are planes, there is a plane/plane distance operation provided, and for points there is point/point Eculidean distance. If one object is a point and the other a plane, there is point/plane perpendicular distance. If both objects are plane segments (in which case the 2nd line would read "DIST FROM SS"), the operation performed is to find the minimum separation of the point-sets enclosed by the polygonal boundaries enclosing the two plane segments. And so on. Hence, the geometric type of each geometric object must be available from the GODA array not only for storage/retreival but for branching to the appropriate operation logic.

In the MILSTAN test being discussed, the next set of GOMP instructions consists of

```
TEST
GE        31.437
AND
TEST
LE        31.563
```

separated by the logical connector AND; note also the AND at the very beginning of this MILSTAN test. Usually a sequence of TEST instructions or OPERATE/TEST combinations are joined by AND connectors if they belong to the same MILSTAN test. The final test results are then the logical conjunction of the individual tests which are connected by AND's. In the above example, the numerical result from the DIST ABOVE operation will have passed the overall MILSTAN test if it is (a) greater than or equal to 31.437 AND (b) less than or equal to 31.563.

If there is only one operation followed by several tests, the general form

```
OPERATE
...
...
```

```
AND
TEST
...
AND
TEST
...
AND
TEST
...
 .
 .
 .
AND
TEST
...
```

can be used - the first AND must precede the first TEST. If more than one operation is to be performed using the same objects, the general form is

```
AND
OPERATE
...
refname1      name1    name2
TEST
...
AND
OPERATE
refname2      USE *
TEST
...
AND
OPERATE
   .
   .
   .
```

AND
OPERATE
refnamen USE *
TEST
...

the object names refname1, refname2, etc. denote reference objects and name1, name2, etc. are the objects being tested for compliance (the test objects). In most MILSTAN tests, a reference object is required, e.g. if name1, name2, ... are points (controls) being tested for compliance with some standard clearance envelope around the DEP, then refname1 is DEP. The operation performed would be point/point distance, to find the distance of each point name1, name2, ..., from refname1, viz.:

OPERATE
DIST FROM
refname1 name1 name2 ... *

Subsequent test may use different reference objects but must use the same test objects name1, name2, etc. To re-use the same test objects, which are still conveniently stored in MILSTAN registers following the first OPERATE instruction, the USE * indicator is used,

OPERATE
refname2 USE *
and so on.

This discussion has wandered somewhat from Example 1, but it has served to illustrate the practical use of the AND, OPERATE, and TEST instructions in sequence. Also, the re-use of test objects via USE * and the introduction of the concepts of test object and reference object have been delineated.

To get back to Example 1, once the TEST instructions have been executed, GOMP has stored the operational result of the DIST ABOVE operation in one of two tables: (a) the PASS table if the distance

of DEP above NUTRLSRP lies between 31.437 and 31.563, or (b) the FAIL table if the distance lies outside this range. Using a FORMAT instruction, the final test result can be printed out by GOMP using the information from the PASS and FAIL tables.

Had there been several test objects (instead of the single object DEP), the operational results for the different objects could be divided between the two tables, and there would be indicators to show which objects belonged to each operational result. Thus, a list of objects which pass the test (or tests) and a list of objects which fail the test(s) are available, along with corresponding numerical operational results (e.g., point/point distances).

GOMP output of this information requires use of the FORMAT instruction. Following the FORMAT input line, subsequent 80 character lines are printed exactly as they appear until a * is encountered within the first ten columns of a line. The next line can start with any kind of instruction (OPERATE, TEST, etc.), but usually a PRT (for "print") instruction is needed. The lines between FORMAT and * (and there need not be any) can be used to provide a readable title for the MILSTAN test. However, it requires a PRT instruction to get the test results printed (the PRT must be preceded by a FORMAT which need not contain any input line before the *).

In the line

```
PRT       SUCCESS   PASS     TOL
```

the word SUCCESS indicates a full printout of test results in a readable phrase e.g.

```
THE FOLLOWING OBJECT DOES NOT SATISFY DIST ABOVE NUTRLSRP EQ
     31.5      TOLRNCE   .063
```

The word PASS has no effect when SUCCESS is present - it is included for consistency and must be present. The word TOL instructs GOMP to treat the result of the two tests (GE 31.437 and LE 31.563) in the following manner: the average of 31.437 and 31.563 (= 31.5) is the actual criterion and this MILSTAN test should be treated as an equality test with an associated

tolerance value ($|31.437 - 31.563|/2 = .063$). Thus the compliance test result, as shown by the sample printout above, is judged successful if the distance above the reference object NUTRLSRP is within .063 inches of 31.5 inches.

If only a single TEST instruction is executed in the MILSTAN compliance test, or if each of a sequence of TESTs is followed by a FORMAT instruction, the word TOL need not appear.

Example 2 (MS33574)

```
OPERATE
DIST      FROM
NUTRLSRP  THRTFWD  *
TEST
LE        25.
FORMAT

MAX FWD THROTTLE - NON-CATAPULT AIRCRAFT
*
PRT       SUCCESS   PASS
TEST
LE        20.
FORMAT

MAX FWD THROTTLE - CATAPULT AIRCRAFT
*
PRT       SUCCESS   PASS
```

In this example, only one OPERATE is to be executed (a single operation, point/point distance, is to be performed). There will be two tests performed on the operational results from the OPERATE execution. However, instead of requiring the numerical operational result (point/point distance between NUTRLSRP and THRTFWD) to satisfy both tests to get a final test result as in the case of Example 1, each test will be

a separate test of the same operational result. This is indicated by (a) the absence of any AND connectors and (b) the presence of a FORMAT instruction with an associated PRT instruction following each test.

Hence, each of the two tests in this example is performed independently (and is only half of the total compliance test being performed). There is no need for the TOL part of the PRT command (in fact, its inclusion would be erroneous), but the presence of "SUCCESS PASS" provides a readable test result for each test, with a format identical to the printout of Example 1 (the tolerance will be zero).

For some compliance tests, the formatting of test results for printout by the "PRT SUCCESS PASS" form is insufficient, and for these cases the formatting should be done largely within the title block included within the range of the FORMAT instruction. To print out the names of the objects satisfying the test(s), together with the numerical operational results in cases where the user provides most of the formatting:

```
PRT     PASS     RES
```

is used. If printout of the list of objects failing the test together with operational results is desired,

```
PRT     FAIL     RES
```

is used.

Example 3.

In this example, a part of the MS33573 test for ejection envelope clearance for the pressure-suited environment is presented. The total test involves locating those control points and cockpit panels which interfere with the ejection envelope, which is defined from the user's input geometry by a combination of standard input planes SEJPN and the design eye point X-coordinate plane (DEPXCP). Only the part of the test dealing with panels will be shown. The MILSTAN test instructions are:

```
FORMAT

ANY PANEL CONTAINED IN THE LAST OF THE FOLLOWING FOUR
LISTS IS INSIDE THE EJECTION ENVELOPE FOR THE PRESSURE-
SUITED ENVIRONMENT
   *
AND
OPERATE
DIST       FROM       S
SEJPN      COMPOSITE ALLPAN
TEST
GE         0.
FORMAT

            LIST 1.  PANELS  FORWARD OF SEJPN
       PANEL          DIST(IN.)

   *
PRT        PASS       RES
AND
OPERATE
DIST       FROM       S
SEJPN      USE *
TEST
LE         30.
FORMAT

            LIST 2.  PANELS    FROM LIST 1. LYING AFT OF EJ.
                     ENV. FRONTAL PLANE
       PANEL          DIST(IN.)

   *
PRT        PASS       RES
AND
OPERATE
```

```
DIST       FROM      S
DEPXCP     USE *
TEST
GE         -15.
FORMAT

                LIST 3.  PANELS     FROM LISTS 1. AND 2. LE 15 IN.
                         LEFT OF DEP
         PANEL            DIST(IN.)

   *
PRT        PASS       RES
AND
OPERATE
DIST       FROM       S
DEPXCP     USE *
TEST
LE         15.
FORMAT

                LIST 4.  THE PANELS IN THIS LIST VIOLATE EJ.
                         ENV. CLEARANCE FOR THE PRESSURE-
                         SUITED ENVIRONMENT
         PANELS           DIST(IN.)


   *

PRT        PASS       RES
```

Note that 4 operations are performed, all using the same set of test objects. The test objects are the crewstation panels, which the user has grouped into composite ALLPAN during the geometry input phase using the

COMPOSE instruction. Note that only the first OPERATE instruction names the composite, and the subsequent operations contain USE * in place of the name COMPOSITE ALLPAN (which need not be followed by a *, since on seeing the word COMPOSITE, GOMP knows there will be only a single name input). During the first operation, GOMP accesses the geometry lying within the ALLPAN composite by the process shown in Figure 3. Thereafter, the panels in ALLPAN are stored compactly in a MILSTAN register for quick access. The USE * in subsequent operations prevents the (Figure 3) table-lookup and staged access process from being repeated for each operation. In addition, the OPERATE/TEST instruction pairs of the example are connected by ANDs, and the USE * is absolutely necessary for the AND connectors to have their intended effect.

Following execution of each OPERATE, geometric storage indices for those panels which fail the following test and moved from the PASS table (which initially contains the indices of all the panels in ALLPAN) to the FAIL table. The AND connectors (together with USE *) cause subsequent OPERATE/TEST failures to be moved from the PASS table to the FAIL table, adding to those indices already in the FAIL table. Thus, an object (in this case a panel) must pass each test in order to remain in the PASS table, or must fail at least one test in order to be moved to the FAIL table.

In the example, the panels which have passed all previous AND-connected OPERATE/TEST tests are those left in the PASS table. Hence, the list printed out using a FORMAT/PRT combination after each OPERATE/TEST gets successively smaller, until at the end it contains only those panels which have passed all tests (hence, violate ejection envelope clearance).

Note the formatting of column headings provided within the FORMAT title block. The "PRT PASS RES" instruction causes only the list of objects from the PASS table, with associated numerical operational results, to be printed as a two-column table.

Note, finally, the "S" occurring in each "DIST FROM" input line. Just as "SS" signifies segment/segment distance, a single "S" signifies that only the test objects are to be treated as segments. Since the two reference objects, SEJPN and DEPXCP, are stored as planes (geometric type GP) and so are the test objects in composite ALLPAN, the operation performed is that of plane/plane-segment distance. This is defined as the distance of closest vertex of the plane segment to the plane. It has zero value if the plane segment intersects the plane. It is a positive value if the plane segment lies in the direction of the normal to the plane and negative if the plane segment lies on the opposite side of the plane. Had the reference object alone been a plane segment and the test objects infinite planes, an "RS" would have been used in place of the "S".

2.1.4 Maintenance

As mentioned in the introduction, there are three components necessary to the execution of the GOMP/MILSTAN MIL-STDS/MIL-SPECS compliance test computer system. These are (a) the computer program, GOMP, and the data base components, (b) MILSTAN, where compliance test instructions for GOMP are stored, and (c) the user's geometry definitions (including composites). The GOMP program is maintained and updated in FORTRAN IV source code form using the BCS MAINSTREAM-EKS UPDATE capability.

The MILSTAN data set is accessed via tape or from permanent file but is basically maintained as a file of IBM cards. Whenever the MILSTAN instruction set is altered, a modified set of cards is read into the computer, and a new tape or disk file is created to replace the old MILSTAN file.

The user crewstation geometry can be maintained in any form, and can be read from card, tape or disk. The user must use the geometry data and GOMP storage instruction formats shown in reference 2. Certain standard objects (including certain points, e.g. the DEP, as well as planes and composites) are essential to getting a significant number of

MILSTAN tests performed on the geometry. These objects should always be included in the user's geometry data set, although no single object is absolutely necessary.

2.2 Phase V Work on the GOMP/MILSTAN System

The current work on the GOMP/MILSTAN computer program/data base system was performed to improve the coverage of MIL-STD and SPEC compliance checking by this system. A total of 51 MIL-STDs/SPECs for fixed wing aircraft, which for various reasons were not previously included on the MILSTAN test instruction data tape, were analyzed for inclusion as coded tests on the MILSTAN tape. Of these, 44 tests were found amenable to being coded into the MILSTAN data file using the present capability of GOMP (Geometric Object Manipulation Program). These 44 tests were coded and the entire MILSTAN instruction set was tested using an augmented A-7E geometry data set for checkout data.

In addition to the analysis of the 51 tests to be added, a review of GOMP program capability and possible improvements was performed. Also, an error in the GOMP computer program and errors in the previously-used A-7E and MILSTAN data sets were corrected.

The GOMP error was in the calculation of the distance from a point P to a convex plane segment with bounding vertices $P_1, P_2, \ldots, P_N$. Subroutine DPTPNS is called from entry point D37 or D73 of subroutine DISTXX to perform this calculation. First, the perpendicular projection P' of P on the plane containing $P_1, P_2, \ldots P_N$ is found. If P' lies within the region $(P_1, P_2, \ldots, P_N)$, the distance $||P - P'||$ is returned ($||\cdot||$ signifies 3-space Euclidean norm). If P' lies outside $(P_1, P_2, \ldots, P_N)$, the distance $||P - P''||$ is returned, where P'' is the boundary point of $(P_1, P_2, \ldots, P_N)$ closest to P. Originally, P'' was determined as the projection of P onto the nearest edge of $(P_1, P_2, \ldots, P_N)$, say (P_i, P_{i+1}). However, in some cases the subroutine returned no answer, for P'' was determined as the projection of P onto the line containing the edge (P_i, P_{i+1}), as shown in Figure 4.

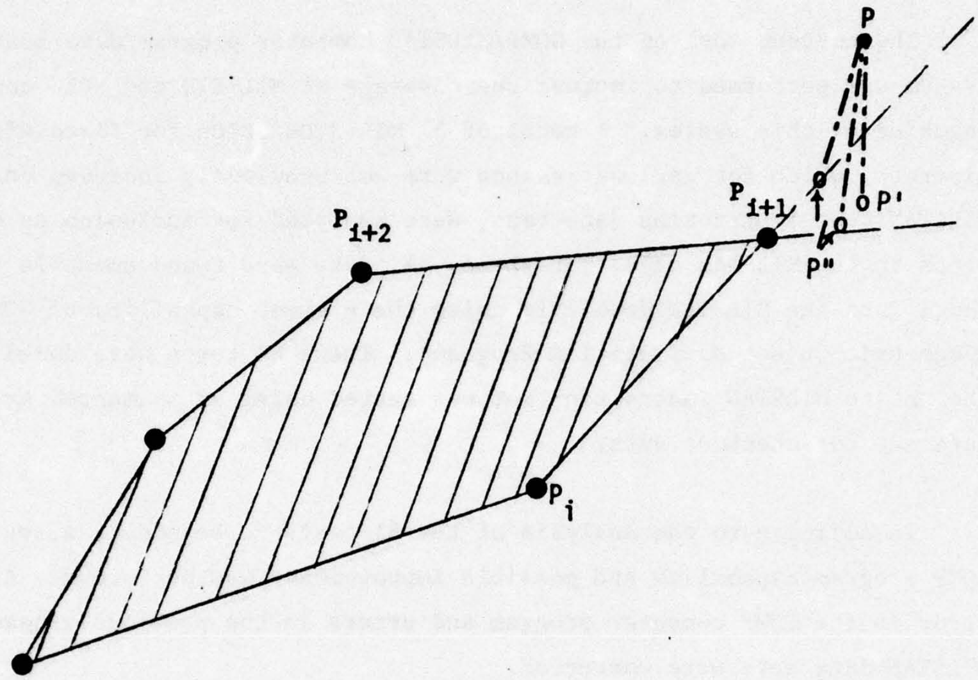

Figure 4. P" Lies Off Edge

If P" could not be found to lie between any pair of adjacent vertices, no answer was returned and the test was cancelled.

The correct response is to let P" be the nearest vertex if P does not project onto any of the edges (P_1, P_2), (P_2, P_3), ..., (P_N, P_1), as shown in Figure 5. This was implemented in subroutine DPTPNS and correct distances were noted in the tests for location of control points MAPSTOW and MAPSTOW2 on the left and right consoles, respectively (this is one of the newly-added MILSTAN tests).

In addition, some of the old tests are affected. One of these is the head clearance requirement at the beginning of MS33573. One of the A7E panels now violates head clearance. Also, the MIL-STD-203E tests "throttle must contain speed brake control" and "seat adjustment on seat" are now executed. Previously, the message "TEST CANCELLED - OBJECTS NOT DEFINED" was printed out due to the faulty return from DPTPNS described above.

The total revisions made to program GOMP in the current effort are as follows:

(a) Correct the error in the point/plane-segment distance calibration,

(b) Increase storage capability for 3-space points, and

(c) Correct a non-fatal condition which produced an annoying "abnormal termination" message at the end of a GOMP execution.

The analysis of added tests is outlined in Appendix A. Additional geometric and composite objects required to perform these tests are outlined in Appendices B and C. The tests were analyzed as presented in Appendix XII of Reference 2 .

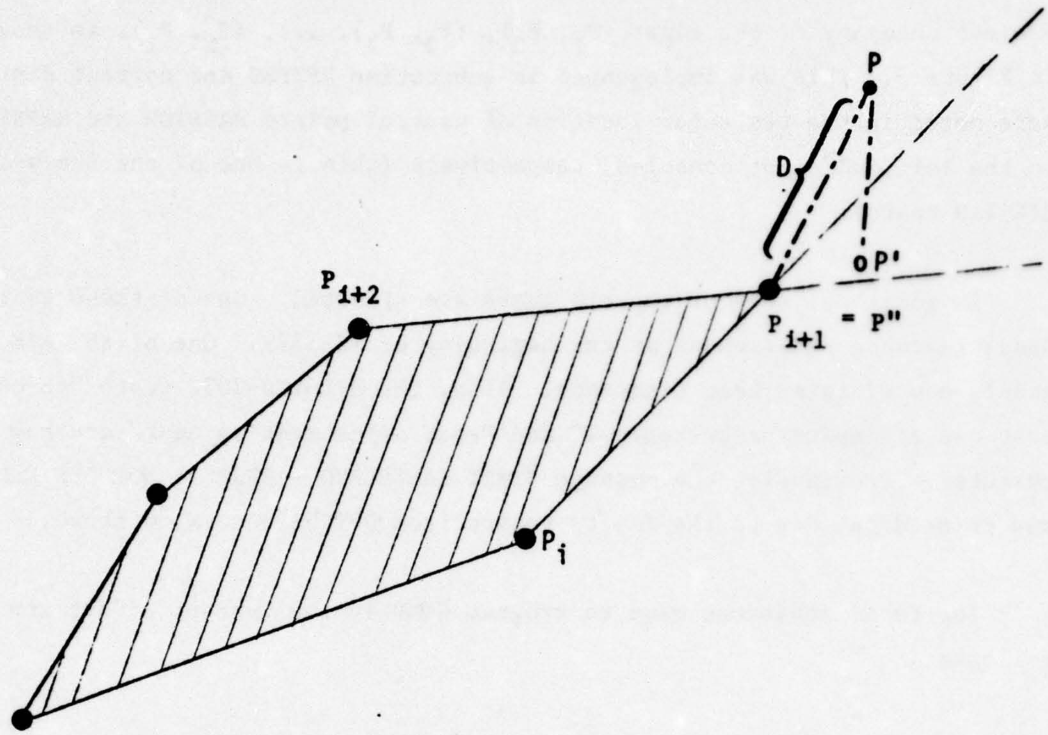

Figure 5. Correct Distance (D)

The A-7E data set errors were as follows:

(a) In the definition of composite ALLCP, the control point name RADGYROE was misspelled as RADGYRDE, leading to its exclusion from all tests involving composite ALLCP.

(b) In the definition of composite SEATPAN, the panel name SRSFWDUP was shifted left one column out of its data field, leading to its exclusion from tests involving composite SEATPAN.

In the previously-used MILSTAN data set, the GOMP instruction ABSVAL was omitted from two tests where absolute value of test results was required. This occurred in the MS33573 head clearance test mentioned above, and also in the MS33575 test, "Rudder pedals neutral adjustment, neutral position must be 35.313 inches from NUTRLSRP". Also, the instruction DIST FWD was inadvertently used in place of the correct form, DIST FORWARD, in several MS33574 tests. In the GOMP test instruction vocabulary, abbreviation of FORWARD to FWD is not legitimate, and the affected tests were cancelled.

The changes to GOMP are included as a set of UPDATE directives in a card deck. This deck can be used to permanently update the GOMP program using the BCS MAINSTREAM-EKS version of the CDC 6600 KRONOS 2.1 UPDATE program. A listing of the UPDATE directives is included along with the augmented A-7E and revised MILSTAN data sets in the sample execution run provided.

The recommendations for further improvements to GOMP are in the remaining paragraphs of this section. The GOMP program as conceived and written has a great deal of potential capability which has never been activated. The recommendations that follow are in the nature of short-term efforts to improve usage and efficiency.

These recommendations are:

(a) Improve the output formats to make MILSTAN test results more readable.

(b) Remove the dependence of the code on geometric storage size. This requires a reorganization of labelled COMMON storage and the recoding of a small number of DIMENSION-dependent IF statements in FORTRAN.

(c) Provide a package of dummy subroutines to replace certain subroutines whose only function is to trace program flow (and print out labelled COMMON storage areas, etc.) for purposes of checkout and error tracing. Although useful when needed, roughly 2500_8 central memory words are occupied by this package. An original set of these subroutines can be kept available and used in place of the dummies when needed.

(d) Roughly 7000_8 words of storage can be saved by decreasing the buffer size for the files INPUT, OUTPUT, TAPE10, and TAPE7 used by GOMP. This requires only replacing the program statement card.

(e) Print out certain informative error messages which are currently printed only if the program is being run in error-tracing mode, as described in (3). Among these are messages which would provide detection of errors in coding new MILSTAN test instructions as well as detection of geometry data errors.

3.0 COMPUTER AIDED DESIGN/CREWSTATION GEOMETRY EVALUATION INTERFACE MODULE

Crewstation geometry descriptions processed by CAD are not compatible with the format used for crewstation geometry descriptions by CGE. The CGE input format for geometry descriptions is much more cumbersome to use than the CAD input format. This is due to the fact that only six points can be used to describe a geometric item in CGE. Because of this, all complex shapes must be subdivided into several component parts in order to provide an accurate description of the item. The CAD Model, on the other hand, does not limit the number of points that can be used to describe a geometric item. It was decided that the user interface with CGE could be greatly simplified if the flexibility of data input inherent in the CAD Model could be extended to CGE.

The CAD/CGE interface was developed during the CAFES Phase V Program. The interface was designed to provide a means of formatting CAD output geometry data so that a crewstation design could be input directly to the CGE for analysis o reach infeasibilities or to test for compliance with military specifications and standards. The first step in the development of this interface was to analyze all differences between the CGE and CAD geometry input formats to determine the specific conversions that would be required to transform CAD output data into CGE input data. The CAD/CGE interface was then designed, coded and integrated into CAFES. A subset of the A-7E cockpit geometry data was used for verification of the new interface. The test case demonstrated that CGE will now accept crew-station geometry data in the output format provided by the CAD/CGE interface. The following section contains a general description of the CAD/CGE interface module, user inputs, model outputs, interface module logic and formats for the interface data bank categories. A CAD/CGE interface module sample problem is contained in Appendix D.

3.1 General Description

The purpose of this module is to retrieve CAD cockpit geometry data from the CAFES data bank, convert it to CGE cockpit geometry format, and

output it in card deck form. The output geometry data will be in design eye reference point (DERP) coordinates. This output deck may then be used, in the same manner as the CDDATA output deck, to prepare input decks for the CGE STORAGE, CSPLOT, and GOMP modules. (See Figure 6.)

Figure 7 shows the data flow for the CAD/CGE interface. In step 1, the user prepares cockpit geometry data in CAD format and inputs it to the CAFES (CAD) data bank. The required cockpit geometry data may already exist in the CAD data bank as a result of previous work.

In step 2, which is totally separate from step 1, the user prepares a set of output specification cards for the CAD/CGE interface module. These cards specify the geometric items and/or subsystems in the CAFES data bank which will be output as cockpit planes, lines and control points. The output specification deck also names a design eye reference point (DERP) and specifies whether the output deck will be in the STORAGE or GOMP format. If STORAGE format is specified (step 2b, Figure 7), the CAD/CGE interface produces a cockpit plane deck and control point deck whose coordinates are in the DERP coordinate system. These two decks will be identical in format to the output decks produced by the CGE CDDATA module. If the GOMP format is specified (step 2a, Figure 7), the CAD/CGE interface produces three decks containing points, lines and planes in the GOMP format.

3.2 User Input Specification

3.2.1 CGE Limitations on Geometry

Geometric input data for all modules of CGE (except GOMP) is limited to bounded planes (maximum of six vertices), points on planes and points in space. GOMP also allows the input of lines connecting two points in space.

In addition, the Boeman Geometry Evaluation (BGE) program imposes the following requirements on input geometry. All cockpit planes must be numbered and planes comprising a three-dimensional object (such as the pilot seat) must have consecutive plane numbers. Cockpit controls must be defined as

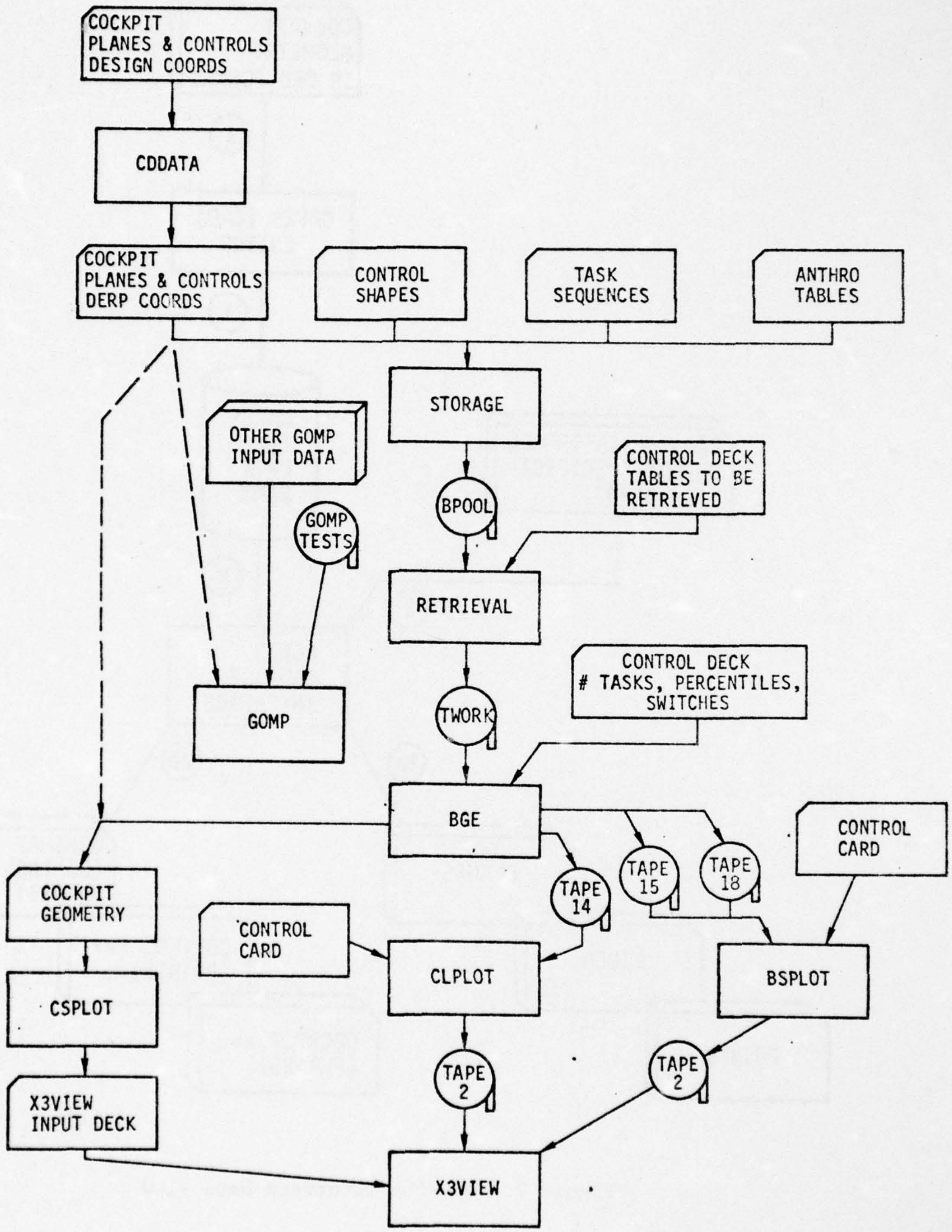

Figure 6. CGE Data Flow

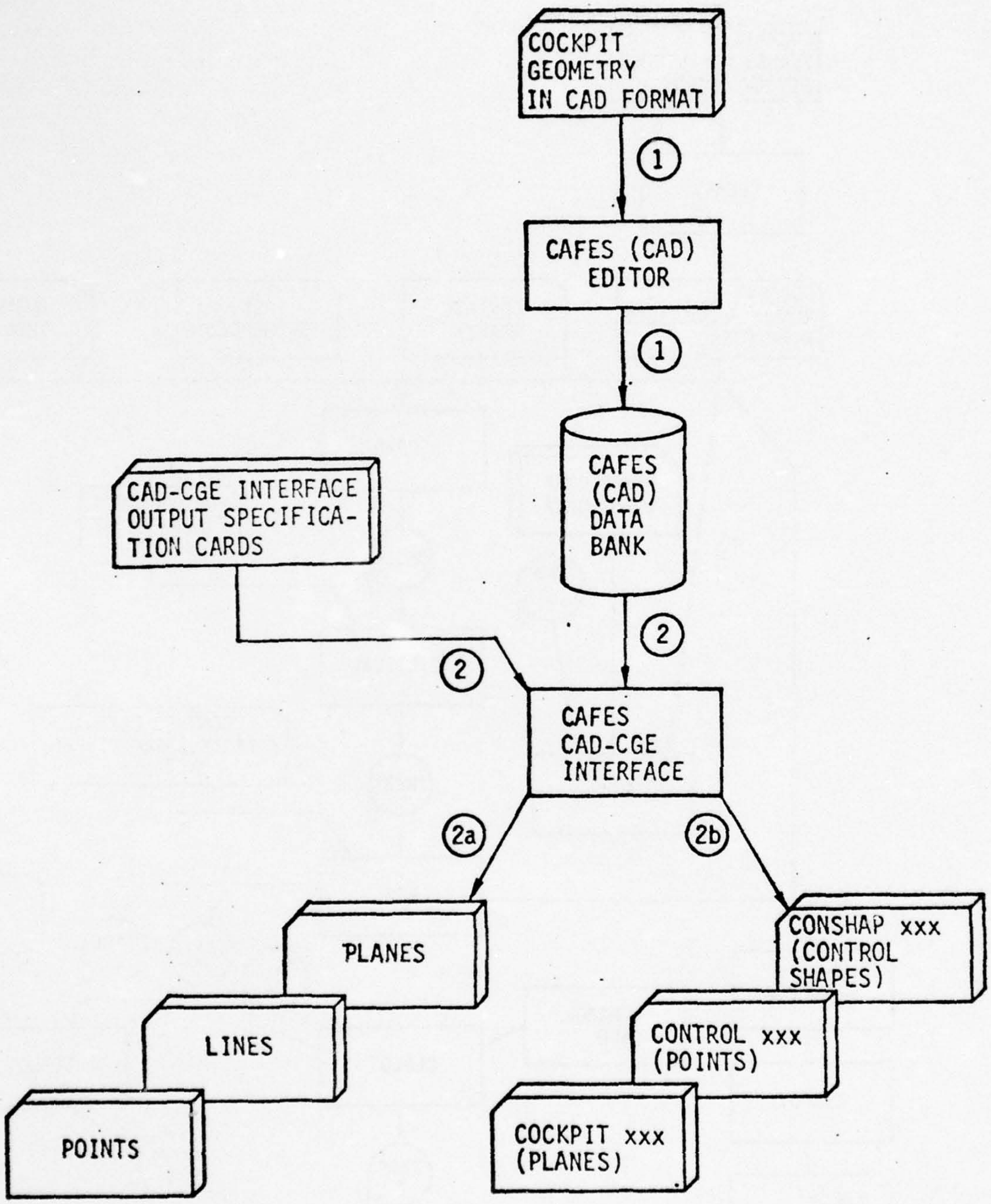

Figure 7. CAD/CGE Interface Data Flow

points on a plane or points in space, and each must have a unique name of up to 10 characters in length. GOMP requires that all geometric objects have 8 character names. Standard names from the GOMP dictionary must be used for geometric objects which are not contained in a composite. The BGE module requires that certain reference points be named with standard names (i.e., "NUTRLSRP" for neutral seat reference point).

3.2.2 Limitations on CAD Geometry

Because of the limitations on CGE input data, the user of the CAD/CGE interface will be constrained in the matter of defining crewstation geometry via the CAD model.

3.2.2.1 Naming Convention

When defining crewstation geometry, the user must conform to the following conventions.

(a) GOMP Data - All cockpit points, lines and planes which will be part of the input data for the GOMP module must be named using the standard GOMP names listed in the CGE user's manual. These names are all 8 characters or less in length.

(b) Other CGE Data - Cockpit planes which will be part of an input data set to a CGE module other than GOMP may have names up to 30 characters in length providing that the first ten non-blank characters form a unique name for the plane. Cockpit points must have unique 10 character (or less) names. Reference points defining the seat position for the BGE module must be named with the standard BGE names (NUTRLSRP, SRPUP, SRDOWN, SRFORW, SRPBACK).

3.2.2.2 Defining Cockpit Objects

When defining three-dimensional cockpit objects such as a seat, the user must define a subsystem exclusively for each object and then must define the object as a series of bounded planes belonging to that subsystem. As an example, a pilot seat might be defined as follows:

```
DEFINE SUBSYSTEM = S.1.1, PILOT SEAT/
SUBSYSTEM = S.1.1/
    DEFINE ITEM = BOUNDARY, SEAT BACK/
        PLANAR DEFINITION = 7.5, 112.75, 274.97,
                            7.5, 99.15, 270.6,
                           -7.5, 99.15, 270.6/
        2D POINTS = 0, 0,   0,30  30,30  30,0/
    DEFINE ITEM = LINES, SEAT PAN/
        PLANAR DEFINITION = 7.5, 99.15, 264.85,
                           -7.5, 99.15, 264.85,
                           -7.5, 100.45, 257.82/
        2D POINTS = 0,0,    0,18.2,  18.2,  18.2,  18.2,0/
    DEFINE ITEM = POINTS, BACK HEAD REST/
        POINTS = 3.5, 134.53, 277.16,
                 3.5, 125.7, 275.72,
                -3.5, 125.7, 275.52,
                -3.5, 134.53, 277.16/
```

As shown in the above example, cockpit planes may be defined as geometric items of the type "POINTS", "LINES", or "BOUNDARY". In the case of a geometric item defined by 3-D points such as the "BACK HEAD REST" shown above, the points defining the item must all be co-planar.

At least three boundary points must be specified for each cockpit plane. There is no limit to the maximum number of points that may be specified, as long as the polygon formed by these points is convex. A cockpit plane whose boundary is concave may not have more than six points defining the boundary.

Cockpit planes and objects to be accessed by the CAD-CGE interface may not contain geometric items of the type, CURVE, CIRCLE, CONIC, ELIPSOID, or POLYHEDRON.

3.2.2.3 Defining Cockpit Lines

The user may define cockpit lines for input to the CGE GOMP module by defining them as geometric items of the type "LINES". The user must define a subsystem exclusively for the cockpit lines.

As an example, the user might define the following lines:

```
DEFINE SUBSYSTEM = S.5.1, GOMP INPUT LINES/
SUBSYSTEM = S.5.1/
     DEFINE ITEM = LINE, ZAXIS/
          POINTS = 0,0,0,   0,0.1/
     DEFINE ITEM = LINE, DEPMCLRY/
          POINTS = 0,0,0,  -2.11,26.519, -14,618/
     DEFINE ITEM - LINE VRAYFWD/
          POINTS = 0,0,0,   0,35.1, -8.5/
```

3.2.2.4 Defining Panels and Controls

The user may define panels as geometric items of the type "PANEL" with instruments and controls defined as elements on the panel. As with other cockpit objects, the user should define a subsystem exclusively for each main panel and its sub-panels.

In the following example, a dummy control type (consisting only of a point) is defined:

```
     DEFINE ELEMENT = CONTROL, POINT/
          REFERENCE POINT = 0,0/
```

Then the left hand console, containing three panels, is defined:

```
     DEFINE SUBSYSTEM = S.3.2, LEFT HAND CONSOLE/
     SUBSYSTEM = S.3.2/
          DEFINE ITEM = PANEL, FWD LH CONSOLE/
```

```
            PANE COORDS = -9.25, 102.03, 244.36,
                          -18.75, 102.03, 244.36,
                          -9.25, 105.09, 240.85/
            BOUNDARY = 0,0,  0,9,  2,9,  3,8,  3,0/
            ELEMENT = POINT, FILDGGRPOS/PLACEMENT = 3.21, 3.7/
    DEFINE ITEM = PANEL, LH CONSOLE/
            PANEL COORDS = -9.25, 101.91, 244.5,
                           -9.25, 101.91, 273.97,
                           -19.96, 101.91, 244.5/
            BOUNDARY = 0,0,  0,29,  9,29,  9,0/
            ELEMENT = POINT, AFCS SWTCH/PLACEMENT = 7.55, 14.2/
            ELEMENT = POINT, CNIADFCHAN/PLACEMENT = 2,2/
            ELEMENT = POINT, CNIIFFMSTR/PLACEMENT = 9,  10.5/
            ELEMENT = POINT, DATALNKCNT/PLACEMENT = 5.7,  3/
    DEFINE ITEM = PANEL, AFT LH CONSOLE/
            PANEL COORDS = -8.52, 101.91, 273.97,
                           -8.52, 101.91, 279.15,
                           -23.03, 101.91, 273.97/
            BOUNDARY = 0,0,  0,15,  6,15,  6,0/
            ELEMENT = POINT, MSPSAGV/PLACEMENT = 2.25, 13.5/
```

An alternate method of defining panels and control points is to define the panels as planes and define the control points as points. A geometric item of the type POINTS that contains only one point is assumed by the CAD-CGE interface module to be a control point.

The following example shows how this method would be used to define the "AFT LH CONSOLE" from the previous example:

```
    DEFINE ITEM = BOUNDARY, AFT LH CONSOLE
         PLANNAR DEFINITION = -8.52, 101.91, 273.97,
                              -8.52, 101.91, 279.15,
                              -23.03, 101.91, 273.97/
         2D POINTS = 0,0,  0,15,  6,15,  6,0/
    DEFINE ITEM = POINT, MSPS AGV/
         POINT = -10.77, 101.91, 276.22/
```

This same panel could also be defined in the following way:

```
DEFINE ITEM = POINTS, AFT LH CONSOLE/
     POINTS = -8.52, 101.91, 273.97,
              -8.52, 101.91, 279.15,
              -23.57, 101.91, 279.15,
              -23.03, 101.91, 273.97/
DEFINE ITEM = POINT, MSPSAGV/
     POINT = -10.77, 101.91, 276.22/
```

The control point "MSPSAVG" in the previous examples would not have to be defined with the panel, but instead could be defined in a separate subsystem with all the other controls.

3.2.2.5 Defining Control Points and Reference Points

The user may define cockpit reference points and control points as geometric items of the type "RP" or the type "POINT". A geometric item of the type "POINT" or "POINTS" that contains only one point is assumed (by the CAD-CGE interface) to be a cockpit control point.

Eye reference points must be of the type "RP" and must define a local coordinate system for the crewmember such that the Z axis points upward, the Y axis is to the crewman's left, and the X axis is in the direction of his line of sight.

The following example illustrates how control and reference points may be defined for the CAD data bank. Before defining any points, the user must define a subsystem exclusively for points and a subsystem exclusively for eye reference points:

```
DEFINE SUBSYSTEM = S.4.1., CONTROL POINTS/
DEFINE SUBSYSTEM = S.4.2, EYE REFERENCE POINTS/
```

Cockpit control points and reference points are then defined for these subsystems:

```
SUBSYSTEM = S.4.2/
DEFINE ITEM = RP, PILOTS ERP/
          POINTS =  41.7, 32.35, 42.33,
                    41.12, 37.35, 42.33,
                    41.7, 30.4, 42.33/
SUBSYSTEM = S.4.1/
DEFINE ITEM = POINT, NUTRLSRP/
          POINT =  41.7, 32.35, 7.13/
DEFINE ITEM = POINT, SRP, UP/
          POINT =  41.95, 32.35, 12.13/
DEFINE ITEM = POINT, SRP, DOWN/
          POINT =  41.5, 32.35, 2/
DEFINE ITEM = POINT, MSPSAVG/
          POINT = -10.77, 101.91, 276.22/
```

3.3 User Output Specification

It is via the output specification commands that the user directs the actions of the CAD-CGE interface. The user will implement execution of the interfaces as follows:

```
BEGIN CGE INTERFACE/
     PUNCH = CAD DATA/
```

The user will specify which CGE module the output data deck is destined for by issuing one of these commands:

```
STORAGE/ or GOMP/
```

With the same command he may specify that the deck be printed as well as punched by including the optional operand "LIST". Example:

```
STORAGE = LIST/ or GOMP = LIST/
```

The user must then specify an eye reference point as follows:

ERP = name/

where "name" is the name of the eye reference point. As required by the CGE modules GOMP and BGE, the coordinates of the output data will be converted to the coordinate system of the associated eye reference point.

An optional command may be inserted at this point to specify the cockpit code and cockpit description:

COCKPIT DESCRIPTION = XXX, description/

where "XXX" is a three-character cockpit code and "description" is a 50-character description of the cockpit.

After specifying the eye reference point, the user must specify the geometry to be included in the output data deck. He specifies this with one or more of the following type commands:

SUBSYSTEM = ddn_1, ..., ddn_{20}/

When each "ddn" is a subsystem Dewey decimal number. From one to twenty subsystems may be specified in each command.

The output specification for a data deck is ended by any other command such as another "PUNCH = " command or an "END CGE INTERFACE/" command.

3.4 The CAD/CGE Interface Logic

The CAD-CGE interface consists of one subroutine within the CGE interface module. The subroutine is named CGCAD. It is called by the main routine CGCGE upon encountering the command "PUNCH=CAD DATA/". It then reads subsequent commands in the following order and takes the following actions.

CGCAD will read one of the following four commands and set switches as follows:

COMMAND	GOMP SWITCH	LIST SWITCH
STORAGE/	cleared	cleared
STORAGE = LIST/	cleared	set
GOMP/	set	cleared
GOMP = LIST/	set	set

The next command must be of the type "ERP = name". CGCAD will call CALTMX to setup a transformation matrix to transform points from the primary coordinate system into the ERP coordinates.

An operational command, COCKPIT DESCRIPTION = code, description/, may be entered at this point. The "description" may be up to 50 characters in length and will be inserted in the descriptor cards for the COCKPITXXX and CONTROLXXX data deck to be punched by CGCAD. The cockpit "code" must be three alphanumeric characters and will be substituted for XXX in the COCKPITXXX, CONTROLXXX and CONSHAPXXX table names. If this command is not entered, the cockpit description in the descriptor cards will be blank.

The next commands must be of the type "SUBSYSTEM = ddn_1, ..., ddn_{20}/". Any number of this type command may be specified and each command may specify from one to twenty subsystems.

CGCAD will process the subsystems one at a time. For each subsystem, a list of the geometric items in the subsystem will be built. Each geometric item will then be processed according to their type and the number of points they contain. Polyhedrons and 3-D surfaces will not be processed. All other geometric items will be treated as control or reference points if they contain one point or are of the type "RP" (reference point), lines if they have two points, and planes if they have three or more points. Geometric items defining lines will be processed only if the GOMP switch is set.

When processing the subsystems and their geometric items, CGCAD will do the following:

(a) Number each cockpit plane consecutively starting with 1.

(b) If the GOMP switch is not set for each subsystem that contains planes, generate a category 100 record where parameter 1 is the subsystem name, parameter 2 is the number of the first plane in the subsystem, and parameter 3 is the number of the last plane in the subsystem. (See Table 1 for category descriptions)

(c) For each geometric item that describes a plane, generate a category 104 record. If the plane is defined by more than six verticies, split it into two or more adjacent planes of six or less verticies.

(d) For each geometric item that describes a point, generate a category 102 record.

(e) If the GOMP switch is set, for each geometric item that describes a line, generate a category 103 record.

(f) For each geometric item that describes a control panel (type "PANEL") generate a category 104 record for the panel plane and a category 102 record for each control or instrument on the panel.

When all subsystems have been processed, CGCAD will then produce the specified output deck. For GOMP, the records in categories 102, 103 and 104 will be processed in that order to produce the GOMP data deck. For STORAGE, the records in categories 104, 102 and 100 will be processed in that order to produce the STORAGE data deck.

3.5 Data Bank Category Formats

The formats for the data bank categories 100, 102, 103 and 104 used by CGCAD are shown in the following tables.

Category Type: Secondary Category Number: 100 Category Name: Cockpit Shapes						
Word	**Parameter Number**	**Variable Name**	**Parameter Name**	**Parameter Type**	**Number of Words or Characters**	**Secondary Category Usage**
1 - 3	1		Cockpit Shape Name - up to 30 characters	Hollerith	30	
4	2		Plane number - lower bound	Integer	1	
5	3		Plane number - upper bound	Integer	1	

Table 1. Format for CGCAD Data Bank Categories

Category Type: Secondary Category Number: 102 Category Name: Cockpit Points						
Word	**Parameter Number**	**Variable Name**	**Parameter Name**	**Parameter Type**	**Number of Words or Characters**	**Secondary Category Usage**
1	1		Control Point Name: COMP - up to 8 characters, BGE - up to 10 characters in length	Hollerith	10	
2 - 4	2		Control Point Coordinates: X, Y, Z	Real	3	
5	3		Plane numbers that control point is imbedded in. Set to -0 if not on a plane	Integer	1	

Table 1. Format for CGCAD Data Bank Categories (cont.)

Category Type: Secondary Category Number: 103 Category Name: Cockpit Lines						
Word	Parameter Number	Variable Name	Parameter Name	Parameter Type	Number of Words or Characters	Secondary Category Usage
1	1		Line Name - Up to 8 Characters	Hollerith	10	
2 - 7	2		Line Coordinates: $X_1, Y_1, Z_1, X_2, Y_2, Z_2$	Real	6	

Table 1. Format for CGCAD Data Bank Categories (cont.)

Category Type: Secondary Category Number: 104 Category Name: Cockpit Planes						
Word	**Parameter Number**	**Variable Name**	**Parameter Name**	**Parameter Type**	**Number of Words or Characters**	**Secondary Category Usage**
1	1		Plane Number	Hollerith	10	
2 - 4	2		Description of Plane - Up to 30 characters long	Hollerith	30	
5	3		Number of Vertices (n)	Interger	1	
6 - 23	4		Vertices of Plane in form: $X_1, Y_1, Z_1, \ldots, X_n, Y_n, Z_n$	Real	18	
24	5		Plane Name - used only for GOMP	Hollerith	10	

Table 1. Format for CGCAD Data Bank Categories (cont.)

4.0 REVIEW OF THE CGE REACH BASKET ANALYSIS COMPUTER PROGRAM

A Reach Basket Model was developed during the CGE Program to provide reach envelopes for crewmen of various sizes. The Reach Basket Model was not completed before the end of the CGE Program. This was unfortunate, since the reach analysis program of the CAD Model requires reach envelope data. Completion of the Reach Basket Model would provide a means to automatically generate the reach envelope data required by CAD.

The CGE Reach Basket Model was examined during the CAFES Phase V Program to obtain an estimate of the resources that would be required to complete and update the model. The original design objectives of the Reach Basket Model were reviewed and evaluated with respect to the CAD reach analysis input requirements and the anticipated demand for reach envelope data for crewmen of various sizes and different seat positions within the cockpit. Particular emphasis was placed upon efficiency improvements and enhancing the user interface. It was concluded that a significant reduction could be achieved in both the amount of core memory and the execution time of the Reach Basket Model by modifying the current optimization routine. It was also concluded that the amount of effort required in terms of manpower and computing requirements to complete the improved optimization model would be justified by a significant reduction in the cost of running the Reach Basket Model.

A discussion of the possible refinements to the Reach Basket Model is contained in the following section. Also included in this section is a new set of documentation for all of the programs that are stored in the Man Model Library. The library contains nine main programs and 92 subprograms that were used to build several different versions of BOEMAN.

4.1 The CGE Reach Basket Analysis Computer Program

4.1.1 Background

The CGE Reach Basket Analysis (RBA) computer program was conceived during the Phase III CGE effort as an add-on item. It was felt desirable

to have a motion-model program similar to the BOEMAN man-model (the BGE model), but adapted to finding reach limits as opposed to simulating motions in a task-oriented fashion. A link-system model using a simple vector geometry approach has been proposed for an RBA model. In this approach, the links are connected with 2 degrees of freedom so that total distance from the base of the link system to a reach point can be calculated.

However, this method neglects the effects of angular limits in the joints of the human link system. Some of these joints, such as the shoulder, have 3 degrees of freedom, as in a universal joint. The upper arm has not only a bend angle θ (relative to some reference bend) in a bend direction ϕ (again, relative to some reference orientation), but has also a torsion or twist angle ψ. Neglecting to model all degrees of freedom with their accompanying excursion limits might yield an inaccurate assessment of human reach capability.

Another disadvantage of simple vector geometry models is that link placements must somehow be calculated. This is not seen to be a trivial problem, especially if spine placement is to be included in the link-system model. An ad hoc or "heuristic" method for link placements would appear to be risky. The placement of a link close to the base of the link-system (e.g., close to the top or the bottom of the spine) can have a very great effect on links close to the end of the system (i.e., the hand or fingertip point). Taking account of these effects to avoid an unstable or a highly inaccurate reach calculation could be complicated.

The CGE motion model used in the BGE computer program avoids both pitfalls. It is structured with all degrees of freedom in the link-connecting joints, and it incorporates an iterative method for solving nonlinear constrained minimization problems to calculate the link placements. Angular limits are readily imposed in the link-system model, and the link placement/orientation angles themselves (Euler angles) are calculated using a general nonlinear equation solution method to force the link system to reach for a point in space or orient itself in some way. The solution process is iterative and allows total freedom of all joint

angles to be varied simultaneously to find a solution. Stability and solution accuracy are controlled by fixing certain parameters in the model to adapt the solution technique, which uses known optimization methods, to the link-system.

4.1.2 Source of the Model

The Reach Basket Analysis model in its present form is simply one of the possible configurations from the Man-Model Development Library (MMDLIB) system (Reference 4). Some of the MMDLIB subroutines exist in a version specifically adapted to reach analysis (RBA version). Others are taken straight from the CGE Phase II motion model (MAN2), which solves for spine position concurrently with arm position. The CGE Phase III motion model (MAN3) has separate body systems, and for simplicity it was decided to use MAN2 for the Reach Basket Analysis version. Since only a one-arm model is used, MAN2 is nearly as efficient for this purpose as MAN3.

The present RBA model was originally developed to "prove the concept", and is not "streamlined" as a finished product. Much unneeded code applicable only to the BGE motion model remains, even in the RBA versions of the specifically adapted subroutines. The Input/Output and environmental interface subroutines, EVALO, INJECT, and RYTE, can be changed to greatly improve usage. The optimization code can be replaced by more efficient, up-to-date codes. Also, the reach analysis optimization package can possibly be reformulated to improve efficiency.

4.1.3 The Link-System Tree Structure

In its most general form, the motion-model link-system is a tree with 6 branches (Figure 8). The origin (both for 3-space Cartesian coordinates and for the tree network) is the bottom of the spine. From this point, three branches emanate. These are the spine, left leg, and right leg systems. The spine system ends at the tip of the spine, and from there emanate three further branches, the head, left arm, and right arm systems. They are joined together in the motion model code by subsequent calls to subroutine TRANSF.

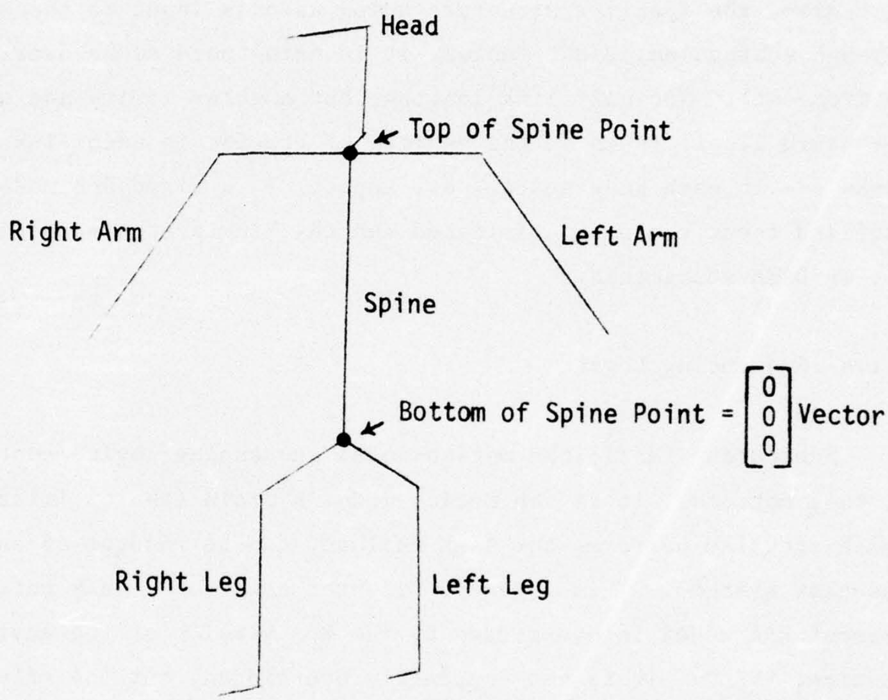

Figure 8. Link-System Tree Structure

Subroutine TRANSF calculates rotation matrices from Euler angles and also returns joint locations for one body system when it is called.

For the BGE model, all six body systems are used. Most of the code for this remains in the RBA model, yet only the spine and one arm, possibly with a simplified head system and a leg system, are needed.

Also, the specific structure being used is input to the motion model through subroutine INJECT (unless it is being used as an overlay in the BGE environment). Not only link lengths, but angular limits and even the link structure itself (such as the degrees of freedom in each link and how many links are in each body system) are input. In a fixed RBA model, this detailed input could be eliminated and the link system structure could be set in DATA statements.

4.1.4 Sequencing Logic

Subroutine TASK1, the motion-model sequencing logic, controls execution of task motions. It is the motion model's brain (the optimization package, which actually performs the task motions, can be thought of as the neuromuscular system). This logic is oriented toward BGE task motions and in the present RBA model is overridden by the RBA version of the environmental subroutine, EVALO. It is not completely overridden, but the effect of having EVALO cancel out some of the task logic is a storage inefficiency. Streamlined versions of these two subroutines would eliminate this.

4.1.5 Optimization Improvements

The optimization package can be replaced with an approximately equivalent capability to save 10,000 octal central memory words on the CDC 6600. Some performance improvements and computer time reductions could be achieved with the improved package, but these are hard to estimate as of this writing. A small additional effort would provide this improvement, since some work has already been done for this report. A certain amount of work remains to maximize the efficiency of the improved optimization package in the motion model. Optimization improvements could be incorporated in the BGE model.

4.1.6 Coding Improvements

Triply-dimensioned arrays in a nested iterative loop procedure are presently used. An improved optimization procedure can reduce the number of iterations and thus, reduce the time required. However, significant timing reductions can also be achieved by speeding up calculations inside the iterati on loops. Elimination of triply-dimensioned arrays and the substitution of singly-dimensioned arrays should be done to speed up the calculations involving those arrays affected.

Recoding some of the labelled COMMON storage can greatly reduce unused space. The Reach Basket Analysis model retains the storage scheme of the original Boeman Geometry Evaluation labelled COMMON it inherits. This provides for storage of 36 link-system connecting points (3 coordinates each) and 36 rotation matrices (3 x 3) and their derivatives. In the RBA, half of these points would be needed at most, and probably fewer. In any case, storage for points and rotations can be cut in half by recoding 3 labelled COMMON statements that appear in 11 subroutines and recoding statements that use the affected arrays.

If all improvements are made, a compact, "fixed" Reach Basket Analysis model will be available. Additional work could enhance performance, but the changes mentioned in this report can be implemented more economically and will greatly reduce the cost of running the RBA computer program.

Timing reduction improvements are hard to forecast as of this writing, hence they are not specified in the following. However, improvements in both computer time and performance will result from the changes mentioned. It should be possible to reduce computer run time of the model by 50% or more. Estimated storage reductions for each of the proposed Reach Basket Analysis improvements are shown in Table 5.

IMPROVEMENT	STORAGE REDUCTION (OCTAL)
1. Fixed link-system tree (reduce input).	400
2. Recode TASK1, EVALO and I/O including buffer size (reduce storage, improve usage).	4500
3. Optimization (reduce storage, cut timing, improve performance).	10000
4. Labelled COMMON (reduce storage, cut timing).	5700
TOTALS	20600

Table 2. Storage Reductions for RBA Improvements

The implementation of these changes could be done in a stepwise manner, with check points along the way. If it becomes obvious at some point that computer run time reductions are not of the order of 50% or greater, development could be limited to achieving storage reductions by recoding portions other than optimization. User improvements, i.e., simpler input and reformatted output, are implicit in this recoding.

4.1.7 Usage of the Current Model

The current model is set up to analyze reach extent for a one-arm model with varying degrees of spine motion (including none). Spine and clavicle restraints, such as seat belts and shoulder straps, are simulated by narrowing the range of freedom in the angular limits for spine and/or clavicle angles. Any link or set of links can be "frozen" by specifying no degrees of freedom. Thus, for the spine, the IQ array (which specifies the links to which variable Euler angles belong) will omit all spine link indices if the spine is to be fixed for a reach analysis.

The reach analysis is performed by specifying the elevations of a set of horizontal planes and rays at various azimuth angle values on the planes. The rays emanate from the Z-axis of the bottom-of-spine reference system, which is the motion-model origin. In this system the Z axis points straight up; X is to the right, and Y is forward in the work station space of the simulated human operator. An annotated listing of the input variables for the Reach Basket Model are contained in Appendix E.

4.2 The CGE Man-Model Development Library (MMDLIB)

During development of the man model (in this discussion "man model" and "motion model" will be used interchangeably) for the Cockpit Geometry Evaluation Computer Program System (CGECPS), a library of related programs and subroutines came into being. This was a result of the different avenues of approach to modeling which were tried, as well as year-to-year refinements and development of ancillary programs for processing data on human subject motions both for research and for statistical validation of the computer model. There are currently 9 main programs and 92 subroutines stored on tape in different versions as separate UPDATE decks in a MAINSTREAM-EKS UPDATE program library file. An annotated listing of these programs and subroutines is contained in Appendix F.

Many of the UPDATE subroutine decks are different versions of certain subroutines which are used in alternate versions of the CGE motion model. These different versions reflect the year-to-year stepwise development effort for and different applications of the motion model. Initially, for example, the motion model had only fixed lower/upper bounds on the Euler angle parameters which vary to move the link system. In subsequent years, variable bounds were introduced for certain Euler angles.

In fact, two different strategies were tried for varying these bounds, and two different versions of the variable-angular-limits model are available as a result. The two strategies have resulted in (a) the Variable Joint Angular Limits model (VJAL) and (b) the Discrete Variable Joint Angular Limits model (DVJAL). In VJAL, the limits are varied continuously during the calculation of a link-system position (using the optimization

procedure in LYNX). Recall that a sequence of positions makes up a man-model task motion. In DVJAL, the varying angular limits are fixed during the calculation of a link-system position, and are then adjusted prior to the next position calculation to "catch up" with the changed link-system configuration. Hence, in DVJAL the limits are varied in a discrete, as opposed to continuous, fashion. The discrete model runs faster on the computer, although the continuous model gives more accuracy in satisfying the limits.

Another version of the motion model resulted from the need for special statistical validation runs. In these runs the computer model (the VAL version) was required to perform a task sequence and then output the data in a special format for a statistical validation program.

The Reach Basket Analysis program is yet another version. Here, the Phase II main program, MAN2, is used in conjunction with the motion model subroutine package with some subroutines deleted and others supplied in a version (the RBA version) specifically adapted to reach basket analysis. For example, the link-system for reach basket analysis (RBA) contains only the spine and one arm. Also, a reach envelope task motion consists of only one position, and the task requirement is to reach as far as possible along a specified reach ray (instead of touching a control point). Hence, the task specification/link system sequencing logic (subroutine TASK1) and programming environment interface (subroutine EVALO) are different for the RBA than for any of the other versions.

At this point, it might be helpful to briefly describe the general structural philosophy of the motion model as a computer program package. There are five main elements in all of the versions of the motion model computer program package (e.g. the RBA version). These are (Figure 9):

(1) The main program, MAN2 or MAN3, depending on whether a Phase II or Phase III type model is to be used (Phase III has separate optimizations for the major body systems, right arm, left arm, head, etc.).

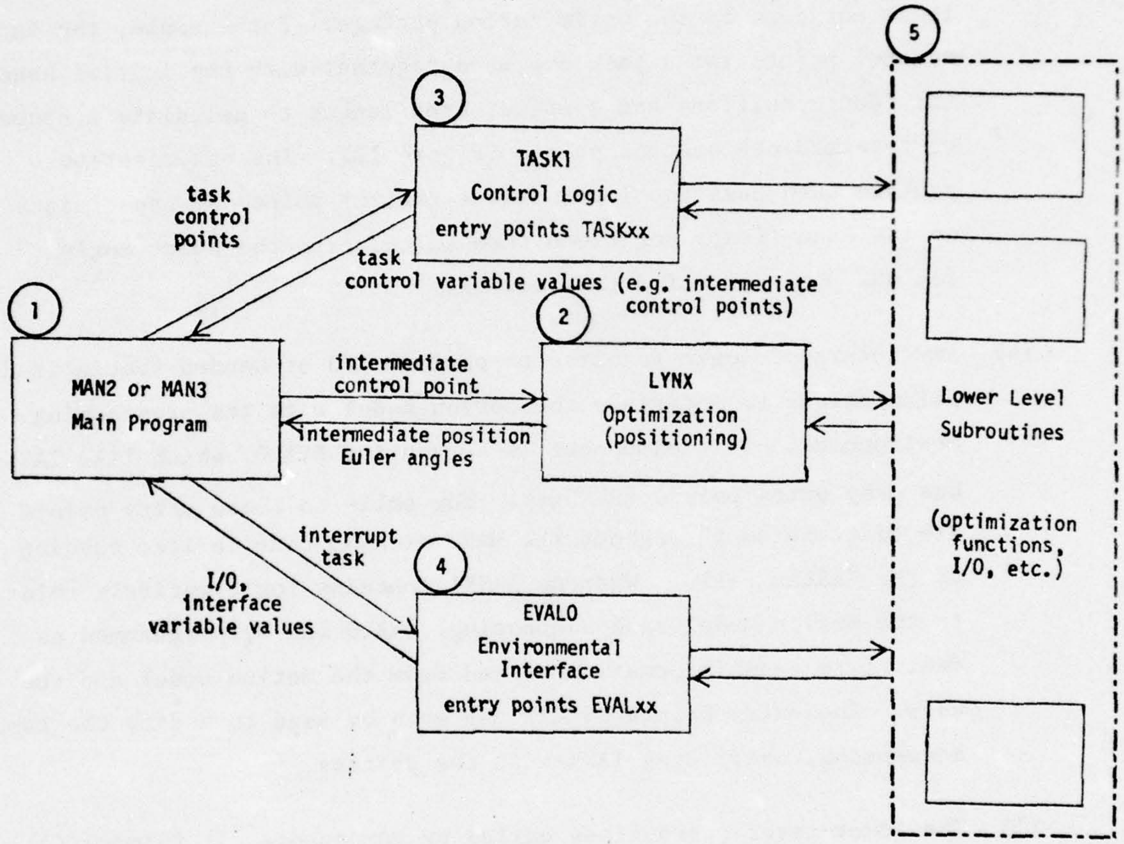

Figure 9. Basic Motion Model Structure

(2) The optimization main subroutine (presently LYNX), which minimizes an "effort" function while requiring the man-model's hands (or feet) to reach certain controls or the eye to view a control. The result of this iterative constrained minimization process is a vector of Euler angles for the link-system joints. This prescribes one position in the motion sequence for one task.

(3) The control logic (subroutine TASK1), which performs all calculations not done by the optimization package. For example, the input control points for a task are used together with the initial hand (or feet) positions and a preset step length to calculate a sequence of intermediate control points (Figure 10). The optimization package then uses the intermediate control points as constraints on the hand (feet) positions when calculating the Euler angles for one positions of a task motion.

(4) Any interface logic required to perform I/O or needed specialized calculations to interface the motion model with its programming environment. This component is subroutine EVAL0, which like TASK1 has many entry points (EVALxx). The calls to these entry points are distributed throughout the MAN2 or MAN3 code in like fashion to the TASKxx calls. Whereas TASK1 contains logic entirely related to the motion model task sequencing, EVAL0 can be programmed as desired to pass information to and from the motion model and the user. The entry points EVALxx can even be used to modify the task sequencing, overriding TASKxx in the process.

(5) The lower-level subroutines called by components (1) through (4) to perform the calculations.

An example of a specific motion model package corresponding to that in Figure 9 is the detailed sketch of the RBA version shown in Figures 11 and 12. Each subroutine is shown as a box with a name, followed by the deck name in parentheses. The deck name is that of the MMDLIB version of the subroutine being used (many subroutines have more than one version, with different deck names). The main program is MAN2, but with the PRØGRAM statement card located in deck MAN2PRG. Hence, the two UPDATE decks MAN2PRG and MAN2 are needed for the RBA version of program MAN2.

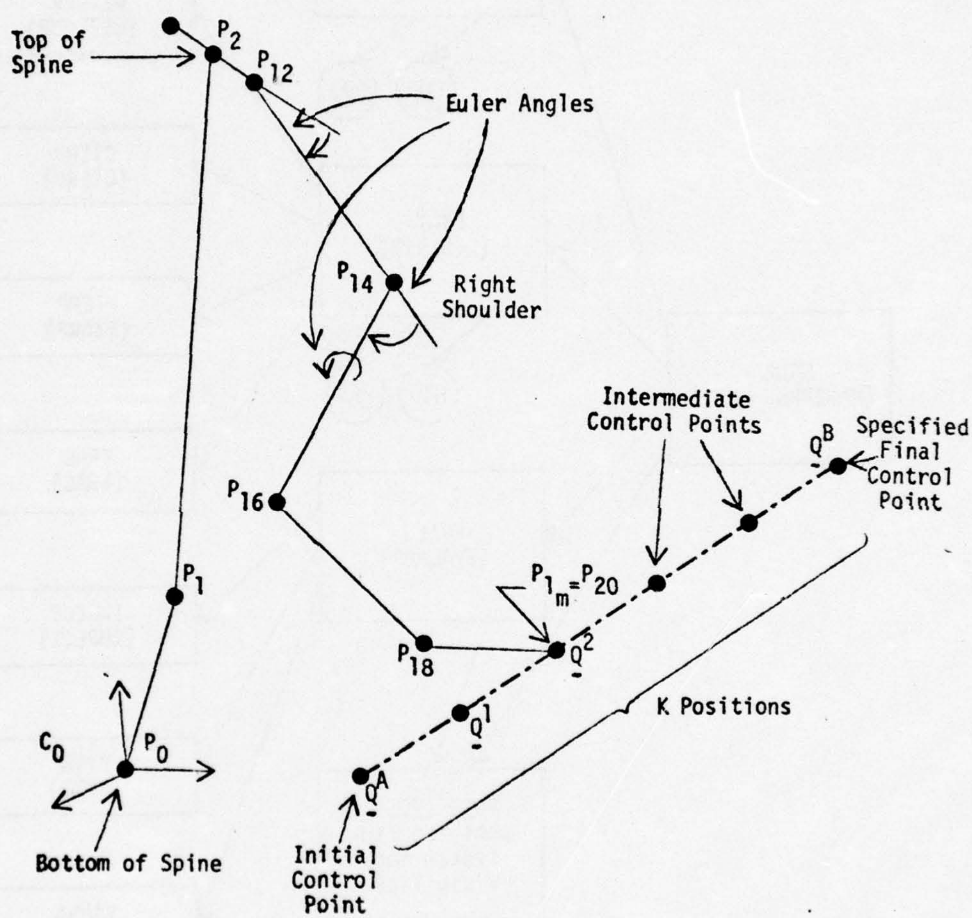

Figure 10. Spine Right Arm System at Position 3 in Motion from $\underline{Q}^A$ to $\underline{Q}^B$

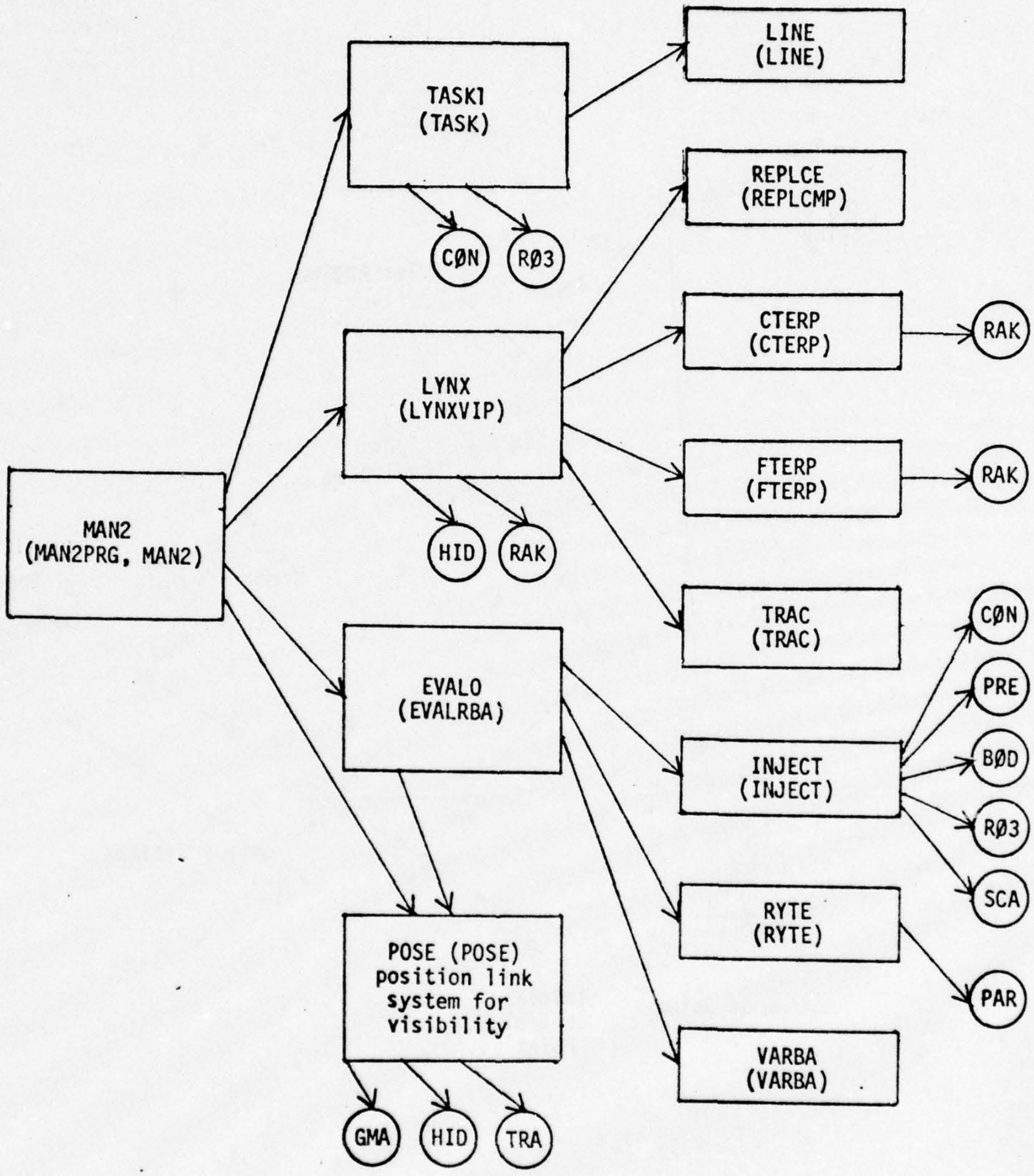

Figure 11. RBA Structure - First 3 Levels

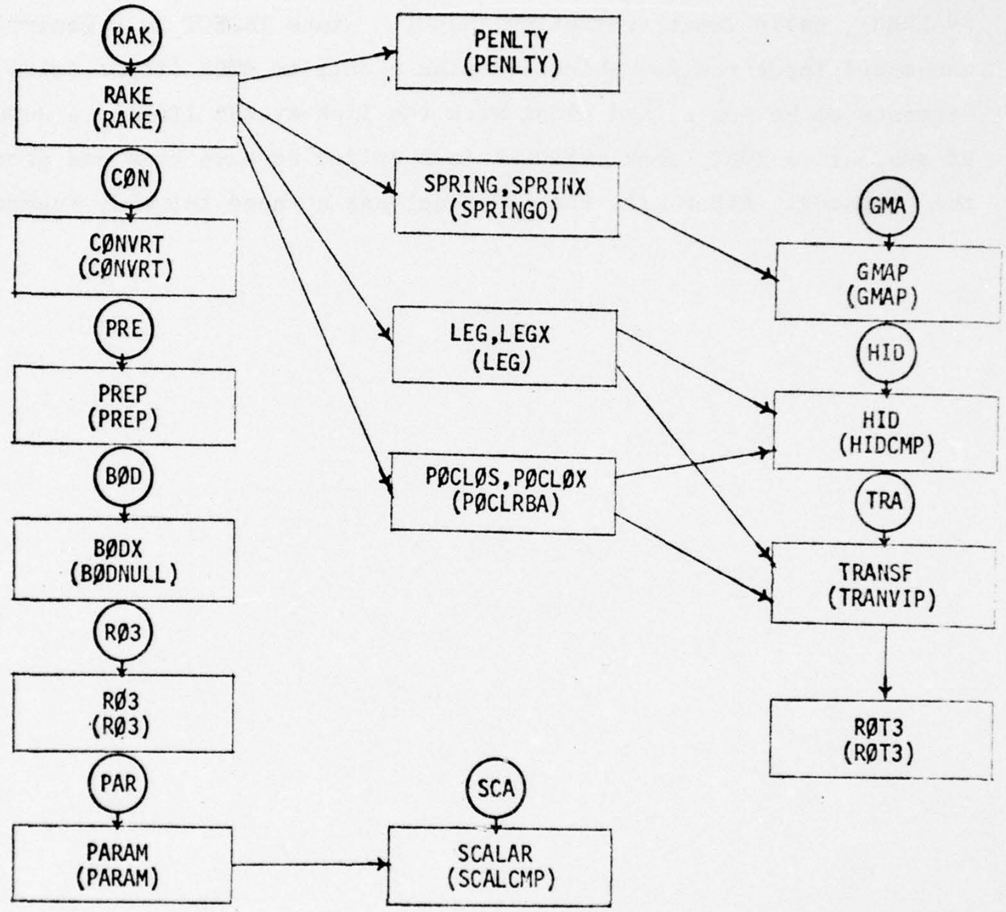

Figure 12. RBA Structure - Levels 4, 5 and 6

For RBA, input from cards is required to specify reach analysis parameters (e.g., the number of horizontal reach planes, the number of horizontal reach rays in each plane, and the spacing of the planes along the vertical Z axis). Hence, interface subroutine EVALO, in its RBA version (deck EVALRBA), calls input subroutine INJECT. Since INJECT is a general purpose man-model input routine which contains a call to BØDX (input solid body segments to be positioned along with the link-system links), a dummy version of subroutine BØDX (deck BØDNULL) is supplied to save time and storage in the computer. After all, the RBA model has no need for body segment solids.

5.0 DATA MANAGEMENT SYSTEM/CREWSTATION GEOMETRY EVALUATION INTERFACE MODULE

The DMS/CGE interface module was developed in Phase V of the CAFES Program to allow the CGE user to employ DMS capabilities for inputting much of the CGE data. To complete this interface, a set of primary and secondary data categories were established to receive input data required by each of the CGE computing functions (crewstation geometry description, BOEMAN, Reach Basket Analysis, GOMP, etc.). The CGE data handled by the DMS includes cockpit plane and control definitions, control shape data, and task sequence data. The execution and report commands of CGE were incorporated under the CAFES executive. Then, a set of data for the A-7E was input to the DMS to demonstrate CGE model input, execution and output via the CAFES DMS. The test case demonstrated that the DMS will accept all of the CGE data categories as inputs and output that data on cards in a format compatible with the CGE input requirements. A description of the user inputs, model outputs, interface logic, and formats for the interface data bank categories is contained in the following section. A DMS/CGE interface module sample problem is contained in Appendix G.

5.1 General Description

The purpose of this module is to allow the CAFES user to input certain CGE data (cockpit plane and control definition and task sequence data) to CAFES in a free field format, store this data in the CAFES data bank, and at user command, retrieve the data and output it in card deck form in CGE format. The output deck containing the cockpit plane and control definitions will have a format identical to the CGE CDDATA input deck. The task sequence output deck will have a format identical to the task sequence input deck for the CGE STORAGE module.

Figure 13 shows the data flow for the DMS/CGE interface. In step 1, the user prepares cockpit geometry and task sequence data in the CAFES free field format and inputs it to the CAFES (CGE interface) EDITOR which stores it in the CAFES (CGE interface) data bank.

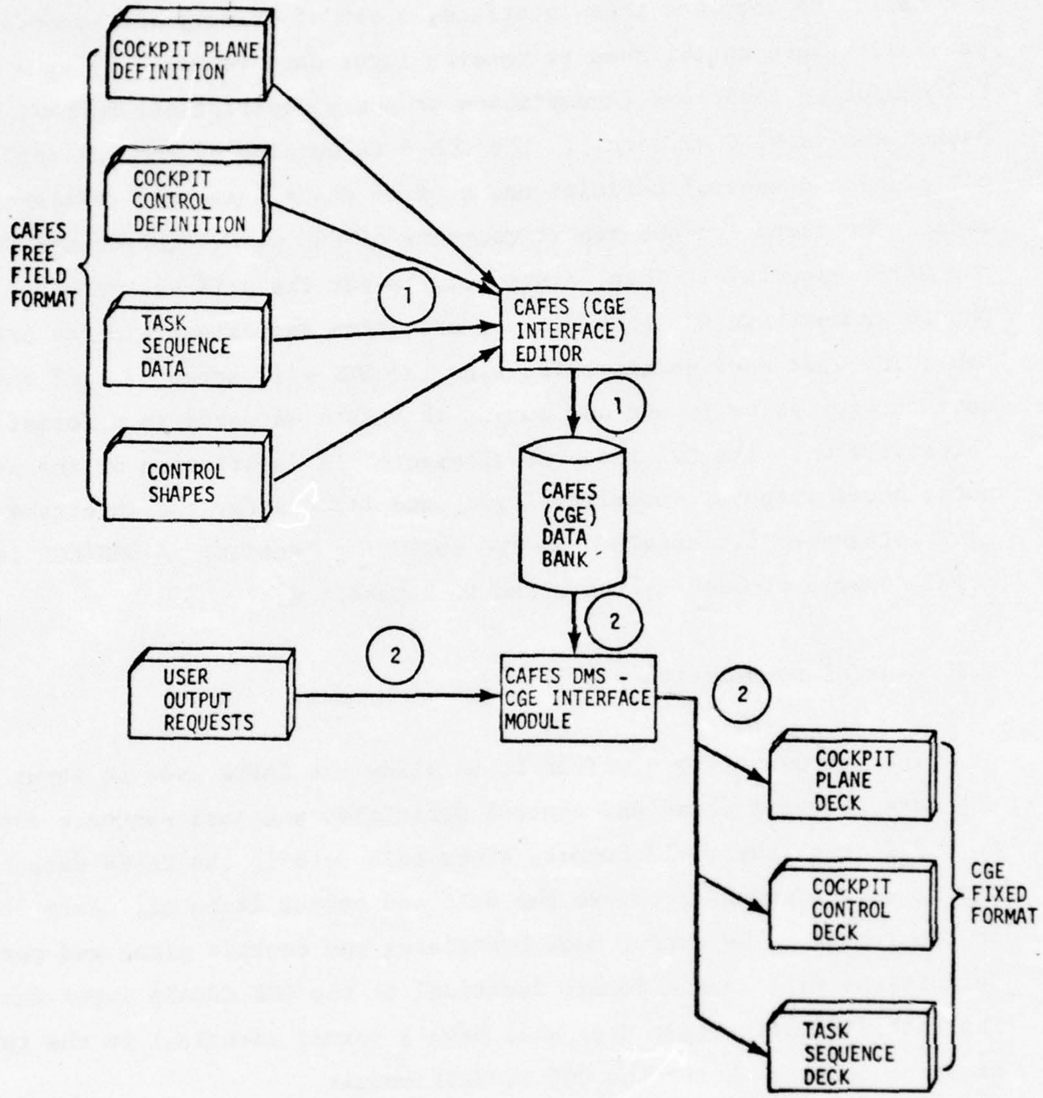

Figure 13. CAFES DMS/CGE Interface Data Flow

In step 2, which is totally separate from step 1, the user prepares a set of output requests for the DMS/CGE interface module. These requests specify which CGE data to retrieve from the CAFES (CGE) data bank. Following the user output requests, the DMS/CGE interface module retrieves the specified data, structures it into the CGE format, and outputs it in card deck form.

5.2 User Input Specification

The CGE input data consists of five parts:

1) cockpit planes data,
2) controls data,
3) eye reference points data,
4) task sequence data, and
5) control shapes data.

The user will initiate the input of this data while in the CAFES EDITOR with the command

```
BEGIN CGE INPUT = (3 character crewstation code)
```

and end the input of this data with the command

```
END CGE INPUT /  .
```

The five major sections of the CGE data will be input using the following commands.

5.2.1 Cockpit Planes Data

The user will utilize the command

```
COCKPIT PLANES = (160 character descriptor) /
```

to tell the program that the cockpit plane definitions are to follow. After this command is executed, the user then inputs each cockpit plane using the following commands.

```
NAME = (30 character name) /
NUMBER = (value) /
VERTICES = (maximum of 6 triplets of values) /
```

5.2.2 Cockpit Controls Data

The user will utilize the command

CONTROLS = (240 character descriptor) /

to tell the program that control definitions are to follow. After this command is executed, the user then inputs each control using the following commands.

CODE = (10 character control code) /

LOCATION = (x, y, z values) /

EMBEDDED PLANE = (value) /

BASE VERTEX = (value) /

5.2.3 Eye Reference Points

The user will utilize the command

EYE REFERENCE POINT /

to introduce a set of eye reference points that follow. After this command is executed, the user then inputs each eye reference point using the following commands.

LOCATION = (x, y, z values) /

NAME = (10 characters) /

5.2.4 Task Sequence Data

The user will utilize the command

TASK SEQUENCES /

to initiate the task sequence subroutine. After this command the user introduces each task sequence with the commands

SEQUENCE = (320 character description) / and

SEQPARM = (1 character sequence parameter) / .

These two commands <u>must</u> be executed prior to the following commands used to define each sequence.

TASK NUMBER = (value) /

TASK DESCRIPTION = (70 characters) /

HAND CONTROL CODES = (10 characters), (10 characters) /

EYE CONTROL CODES = (10 characters) /
FOOT CONTROL CODES = (10 characters), (10 characters) /
HAND GRIP CODES = (value), (value) /
DURATION TIME = (value) /
HOLDING TIME = (value) /
EULER ANGLES = (4 sets of x, y, z points) /

5.2.5 Control Shapes Data

The user will utilize the command

CONTROL SHAPES = (240 character descriptor) / .

After this command is executed, the user then inputs each control shape using the following commands.

NAME = (30 characters) /
PLANE BOUNDARIES = (value), (value) /

5.3 User Output Specification

Two types of output are provided by the DMS/CGE interface module; printed reports and a punched card deck.

5.3.1 Printed Output

A data bank report is obtained as follows.

```
BEGIN REPORT GENERATOR /
     REPORT = CGEDATA /
END REPORT GENERATOR /
```

This report provides the user with a formatted output of the following:

a. CGE cockpit plane data,
b. CGE cockpit controls data,
c. CGE task sequence data,
d. CGE cockpit shapes data,and
e. CGE eye reference point data.

From this report the user may easily scan his input data to check for consistency and accuracy.

5.3.2 Punched Output

In order to obtain an output deck of cards properly formatted in CGE format, the user will use the following commands.

```
BEGIN CGE INTERFACE /
     PUNCH = CGEDATA
          TASK SEQUENCES = [LIST]
          CONTROL SHAPES = [LIST]
          CDDATA = (LIST)
               EYE REFERENCE POINT = (name) /
END CGE INTERFACE /
```

The parameter list enclosed in brackets is an option parameter. If the user specifies the LIST option, a card image listing of the punched output is obtained as it is being generated. If the LIST parameter is not specified, no listing is obtained.

The TASK SEQUENCES and CONTROL SHAPES commands will punch a deck of cards from the data bank in CGE STORAGE format. The output and formats are shown in Tables 3 and 4.

The user may have supplied more than one eye reference point when the data bank was built initially. Thus, when the CDDATA punched output is desired, the additional command, EYE REFERENCE POINT = (name) /, is needed to select the desired eye reference point from those previously stored. The (name) is the name of the eye reference point desired (parenthesis not included).

The CDDATA command will punch cards in CGE CDDATA format. The output formats are given in Table 5. Since three commands are necessary for obtaining all the punched output, the user may specify any combination of these commands and receive a punched deck just for that combination.

5.4 The DMS/CGE Interface Logic

5.4.1 Editor Subroutines

TASK SEQUENCES FORMAT

Record Number	Record Type	Record "Column"	Record Format	Mnemonic	Description
(n_4+1) to (n_4+4)	Task Sequence	1-80	A10	DUM1,DUM2, DUM3,DUM4	Task sequence descriptors (dummies) for TASKSEQyxx
(n_4+5)		1-2	I2	NT1	Total number of tasks in the task sequence.
$(n_4+5)+(3i-2)$		1-3	I3	TASKNØ(I)	Dimensioned (20), Task number
		11-80	7A10	TDES(K,I) (K=1,7)	Dimensioned (7,20), 70 character task description
$(n_4+5)+(3i-1)$	Task Sequence (cont.)	1-10	A10	RHTC(I)	Dimensioned (20), Right hand control code
		11-20	A10	LHTC(I)	Dimensioned (20), Left hand control code
		21-30	A10	ETC(I)	Dimensioned (20), Eye control code
		31-40	A10	RFTC(I)	Dimensioned (20), Right foot control code

Table 3. DMS/CGE Task Sequence Format

TASK SEQUENCES FORMAT (CONTINUED)

Record Number	Record Type	Record "Column"	Record Format	Mnemonic	Description
		41-50	A10	LFTC(I)	Dimensioned (20), Left foot control code
		51	I1	RHGC(I)	Dimensioned (20), Right hand grip code
		56	I1	LHGC(I)	Left hand grip code for each code, 1=extended hand 3=clenched hand
		61-67	F7.3	TDUR(I)	Dimensioned (20), Task duration time
		68-78	F11.3	THØLD(I)	Dimensioned (20), Holding time at end of task
$(n_4+5)+$ 3i	Task Sequence (cont.)	1-15	3F5.0	RHØRT(L,I) (L=1,3)	Dimensioned (3,20), Euler angles for right hand orientation (Theta, Phi, Psi)
		16-30	3F5.0	LHØRT(L,I) (L=1,3)	Dimensioned (3,20), Euler angles for left hand orientation (Theta, Phi, Psi)
		31-45	3F5.0	RFØRT(L,I) (L=1,3)	Dimensioned (3,20), Euler angles for right foot orientation (Theta, Phi, Psi)
		46-60	3F5.0	LFØRT(L,I) (1=1,3)	Dimensioned (3,20), Euler angles for left foot orientation (Theta, Phi, Psi)

NØTE: These three card images are repeated for i=1 to NT1. The last card image is denoted n_5.

Table 3. DMS/CGE Task Sequence Format (cont.)

CONTROLS SHAPES FORMAT

Record Number	Record "Column"	Record Format	Description
1 to 3	80	8A10	Control shapes descriptor
3 + i	1-30	3A10	Control shape name
3 + i	31-35	I5	Lower plane boundary
3 + i	36-40	I5	Upper plane boundary

Table 4. DMS/CGE Control Shapes Format

CDDATA FORMAT

RECORD NUMBER	RECORD COLUMN	RECORD FORMAT	MNEMONIC	DESCRIPTION
1	1-5	I5	NERP	TOTAL NUMBER OF EYE REFERENCE POINTS IN CREW STATION.
2 TO (NERP+1)	1-24	3F8.3	ERP(I,J) (I=1,3; J=1,NERP)	LOCATION OF EACH COCKPIT EYE REFERENCE POINT IN DESIGN COORDINATES (BUTTOCK, WATER, STATION LINES)
NERP+2	1-5	I5	IERP	EYE REFERENCE POINT NUMBER TO BE USED.
	6-15	A10	ERPNAM	DESCRIPTIVE 10 CHARACTER NAME OF CHOSEN EYE REFERENCE POINT.
NERP+3 NERP+4	1-80	8A10	DESC(I,J) (I=1,2; J=1,8)	TWO COCKPIT DATA DESCRIPTOR CARDS.
NERP+5	1-3	I3	NPLANE	TOTAL NUMBER OF COCKPIT PLANES
	1-37	3A10, A7	PLNAM(I,J) (I=1,4; J=1, NPLANE)	COCKPIT PLANE NAME
I	38-40	I3	JPL(J) (J=1, NPLANE)	COCKPIT PLANE NUMBER
	41-42	I2	NV(J) (J=1, NPLANE)	NUMBER OF VERTICES
I+1,I+2	1-72	9F8.2	PPT(K,I,J) (K=1,3;I=1 NV(J);J=1 1,NPLANE	COCKPIT PLANE VERTICES IN DESIGN COORDINATES

RECORDS I, I+1, I+2 ARE REPEATED UNTIL ALL "NPLANE" PLANES ARE SPECIFIED.

Table 5. CDDATA Format

CDDATA FORMAT

(continued)

RECORD NUMBER	RECORD COLUMN	RECORD FORMAT	MNEMONIC	DESCRIPTION
(M+1), (M+2), (M+3)	1-80	8A10	DESK(I,J) (I=1,2; (J=1,8)	CONTROLS DATA SET DESCRIPTOR CARDS.
M+4	1-3	I3	NCC	NUMBER OF CONTROL CODES
J	1-10	A10	CCØDE(J) (J=1,NCC)	CONTROL CODE UP TO 10 CHARACTERS.
	11-40	3F10.3	C(I,J) (I=1,3; J=1,NCC)	CONTROL POINT COORDINATES OR DISTANCES, ALONG X & Y EDGES, FROM SPECIFIED VERTEX IVNØ (3RD OR "Z" - COORDINATE BLANK)
	43-45	I3	IP(J) (J=1,NCC)	PLANE NUMBER OF EMBEDDED CONTROL (BLANK IF NOT EMBEDDED)
	48-50	I3	IVNO(J) (J=1,NCC)	VERTEX NUMBER ON PLANE NUMBER IP(J) TO BE USED AS ORIGIN IN CALCULATING X, Y, Z COORDINATES OF CONTROL POINT.

RECORD J IS REPEATED UNTIL "NCC" CONTROL POINTS HAVE BEEN SPECIFIED.

Table 5. CDDATA Format (cont.)

When the command BEGIN CGE INPUT is encountered, the CAFES editor subroutine CGEGE will be entered. This is a control program which will call five other subroutines. These subroutines are as follows.

CEPLANE - reads cockpit planes data nad places it in the cockpit planes category.

CECODE - reads cockpit controls data and places it in the cockpit controls category.

CEEYE - reads eye reference point data and places it in the eye reference category.

CETSK - reads task sequence data and places it in the task sequence category.

CESHAP - reads control shapes data and places it in the control shapes category. In addition, the main program will store the description in the CGE descriptor category.

A macro flowchart of this process is shown in Figure 14.

5.4.2 Report Generation Subroutines

When the command

REPORT=CGEDATA

is encountered while in the Report Generation mode, a formatted output of all CGE data stored in the data bank is obtained. Subroutine CRCGE is used to produce this output. Subroutine CRCGE is entered when a command of the form

REPORT=CGEDATA/

is encountered while in the Report Generation mode. This routine provides a complete formatted dump of all data stored in the CGE data bank categories 81 through 87. Since this routine is a data bank report routine, it is a part of OVERLAY (CAFES, 3, 1).

5.4.3 DMS/CGE Interface Module Subroutine

Program CGCGE is the main overlay program for controlling the generation of data for the CGE program. The data is generated in two possible ways. The first is simply to output previously stored CGE data from the data

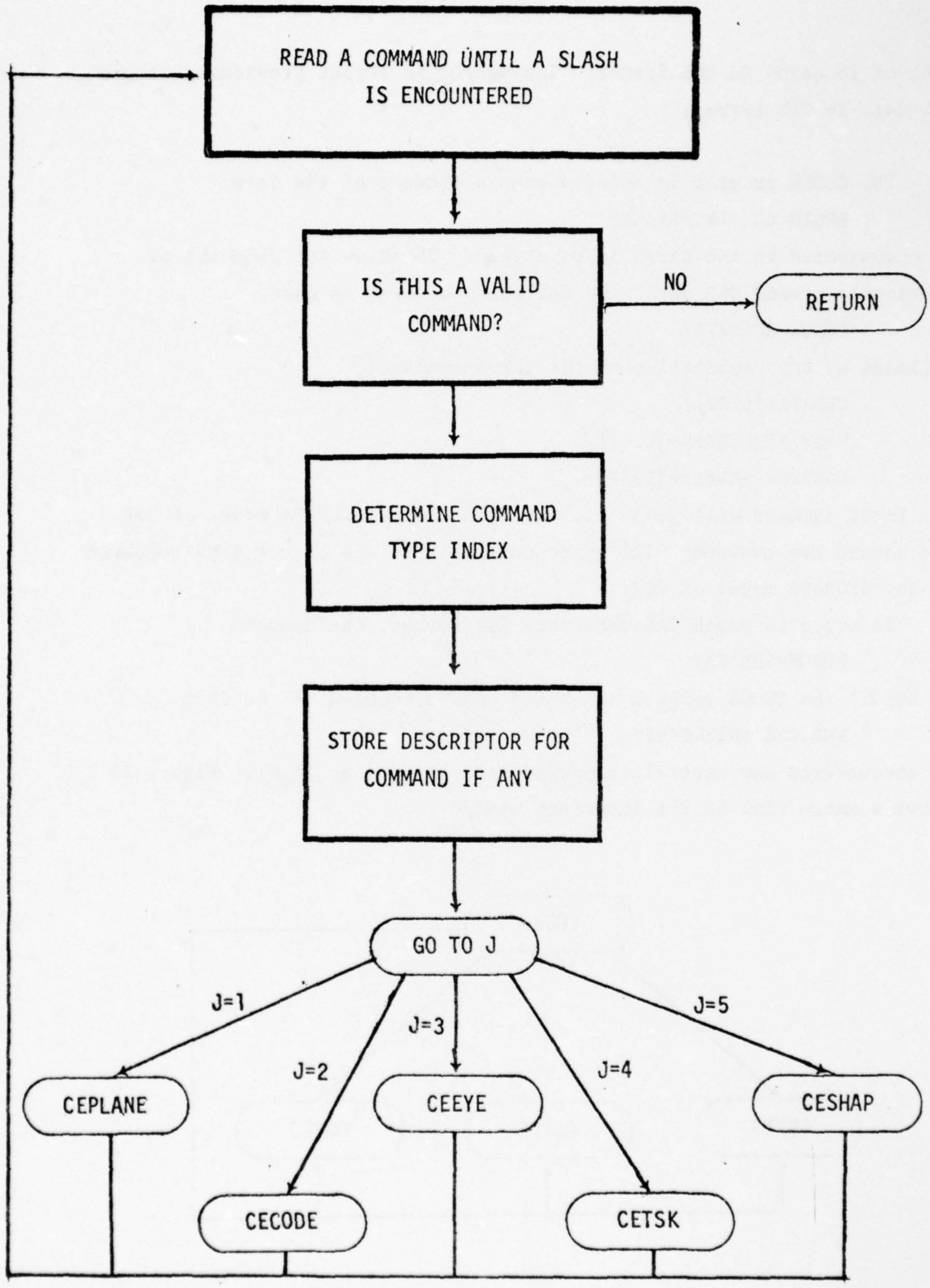

Figure 14. Macro-Flow of CECGE

bank on to cards in CGE format. The second is output previously stored CAD data in CGE format.

The CGCGE program is entered when a command of the form

BEGIN CGE INTERFACE/

is encountered in the CAFES input stream. To allow for punching of previously stored CGE data, the following command is used.

PUNCH CGEDATA/

followed by any combination of the three commands,

CDDATA=[LIST]/

TASK SEQUENCES=[LIST]/

CONTROL SHAPES=[LIST]/.

The first command will punch out the data for the CDDATA model of CGE. The second two commands will punch out two portions of the data required by the STORAGE model of CGE.

In order to punch CAD data into CGE format, the command

PUNCH=CDDATA/

is used. The CGCGE program is exited when a command of the form

END CGE INTERFACE/

is encountered and control is passed back to overlay (1,0). Figure 15 shows a macro flow of the interface module.

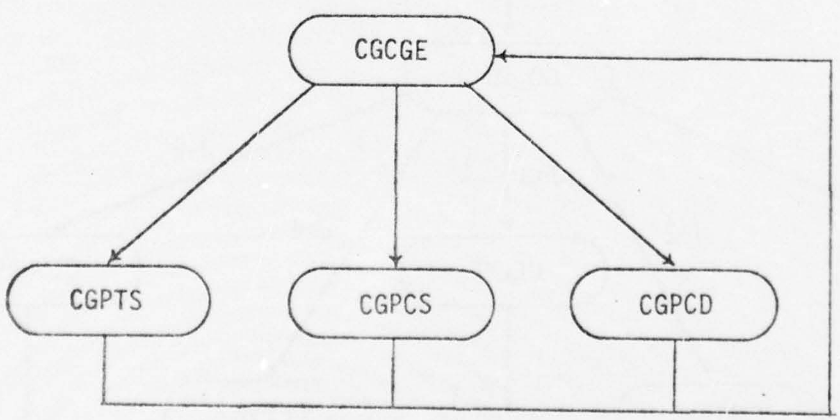

Figure 15. CAFES/CGE Interface Module Flow

5.5 Data Bank Category Formats

The formats for the DMS/CGE Interface Module data bank categories are shown in the following tables.

Category Type: PRIMARY Category Number: 81 Category Name: CGE DESCRIPTORS						
Word	Parameter Number	Variable Name	Parameter Name	Parameter Type	Number of Words or Characters	Secondary Category Usage
1	1		COCKPIT PLANE DESCRIPTOR	CHARACTER	16	
17	2		CONTROLS DESCRIPTOR	CHARACTER	24	
41	3		CONTROL SHAPES DESCRIPTOR	CHARACTER	24	
65	4		CREW STATION NAME (3 CHARACTERS)	CHARACTER	1	

Table 6. Format for DMS/CGE Data Bank Categories

Category Type: PRIMARY Category Number: 82 Category Name: COCKPIT PLANES						
Word	Parameter Number	Variable Name	Parameter Name	Parameter Type	Number of Words or Characters	Secondary Category Usage
1	1		PLANE NAME	CHARACTER	4	
5	2		PLANE NUMBER	INTEGER	1	
6	3		NUMBER OF VERTICES	INTEGER	1	
7	4		VERTICES (X, Y, Z GROUPS)	FLOATING	18	

Table 6. Format for DMS/CGE Data Bank Categories (cont.)

Category Type: PRIMARY
Category Number: 83
Category Name: COCKPIT CONTROLS

Word	Parameter Number	Variable Name	Parameter Name	Parameter Type	Number of Words or Characters	Secondary Category Usage
1	1		CONTROL CODE	CHARACTER	1	
2	2		LOCATION (X, Y, Z)	FLOATING	3	
5	3		EMBEDDED PLANE	INTEGER	1	
6	4		BASE VERTEX	INTEGER	1	

Table 6. Format for DMS/CGE Data Bank Categories (cont.)

Category Type: PRIMARY Category Number: 84 Category Name: EYE REFERENCE POINTS						
Word	**Parameter Number**	**Variable Name**	**Parameter Name**	**Parameter Type**	**Number of Words or Characters**	**Secondary Category Usage**
1	1		EYE REFERENCE POINT NAME	CHARACTER	1	
2	2		LOCATION (X, Y, Z)	FLOATING	3	

Table 6. Format for DMS/CGE Data Bank Categories (cont.)

Category Type: PRIMARY

Category Number: 85

Category Name: TASK SEQUENCES

Word	Parameter Number	Variable Name	Parameter Name	Parameter Type	Number of Words or Characters	Secondary Category Usage
1	1		TASK NUMBER	INTEGER	1	
2	2		TASK DESCRIPTION	CHARACTER	7	
9	3		RIGHT HAND CONTROL CODE	CHARACTER	1	
10	4		LEFT HAND CONTROL CODE	CHARACTER	1	
11	5		EYE CONTROL CODE	CHARACTER	1	
12	6		RIGHT FOOT CONTROL CODE	CHARACTER	1	
13	7		LEFT FOOT CONTROL CODE	CHARACTER	1	
14	8		RIGHT HAND GRIP CODE	INTEGER	1	
15	9		LEFT HAND GRIP CODE	INTEGER	1	
16	10		TASK DURATION TIME	FLOATING	1	
17	11		HOLD TIME AT END OF TASK	FLOATING	1	
18	12		EULER ANGLES FOR RIGHT HAND ORIENTATION	FLOATING	3	
21	13					
21	13		EULER ANGLES FOR LEFT HAND ORIENTATION	FLOATING	3	
24	14		EULER ANGLES FOR RIGHT FOOT ORIENTATION	FLOATING	3	
27	15		EULER ANGLES FOR LEFT FOOT ORIENTATION	FLOATING	3	

NOTE: This category may contain several sets of tasks which form a unique task sequence. The task sequence descriptor and task sequence set number is given in category 87.

Table 6. Format for DMS/CGE Data Bank Categories (cont.)

Category Type: PRIMARY Category Number: 86 Category Name: CONTROL SHAPES						
Word	Parameter Number	Variable Name	Parameter Name	Parameter Type	Number of Words or Characters	Secondary Category Usage
1	1		CONTROL SHAPE NAME	CHARACTER	3	
4	2		UPPER PLANE BOUNDARY	INTEGER	1	
5	3		LOWER PLANE BOUNDARY	INTEGER	1	

Table 6. Format for DMS/CGE Data Bank Categories (cont.)

Category Type: PRIMARY Category Number: 87 Category Name: TASK SEQUENCE DESCRIPTOR & SET NOS.						
Word	Parameter Number	Variable Name	Parameter Name	Parameter Type	Number of Words or Characters	Secondary Category Usage
1	1		TASK DESCRIPTOR	CHARACTER	32	
33	2		TASK SEQUENCE NUMBER (1 CHARACTER)	CHARACTER	1	
34	3		SET NUMBER	INTEGER	1	
35	4		NUMBER OF RECORDS IN SET			

NOTE: These set numbers correspond to the sets generated in category 85.

Table 6. Format for DMS/CGE Data Bank Categories (cont.)

6.0 CONSOLE SPACE OPTIMIZATION AND LAYOUT EVALUATION MODEL (CONSOLE)

The capability of the Computer-Aided Design (CAD) Model to describe controls and displays was extended during Phase V of the CAFES Program by the specification of preliminary requirements for a CONsole Space Optimization and Layout Evaluation (CONSOLE) Model. The first step in this effort was to define the general requirements for an automated panel space allocation routine. Then, a survey of the literature on computer-aided optimization techniques was conducted. Since an adequate computer-aided method for allocating panel space and for arranging controls and displays was not found, a new procedure was developed. Ground rules for the new computer model were established. An appropriate function for the allocation of panel space was defined and the parameters to be used in the optimization routines were identified. From this base, an analytical approach was developed for the CONSOLE Model.

CONSOLE is being developed to assist crewstation designers in determining the optimal size and spatial arrangement for functionally related groups of controls and displays. The following section will contain a description of the general requirements and objectives of the CONSOLE Model, the CONSOLE concept, and CONSOLE input requirements, computing routines and outputs.

6.1 Introduction

The purpose of this specification is to provide a broad outline of desired capabilities and a set of general requirements for an initial conceptualization of a CONSOLE Space Optimization and Layout Evaluation (CONSOLE) Model. CONSOLE will be developed as a submodel of the Computer-Aided Design (CAD) Model and will operate, initially, in a batch mode. The overall objective of CAD is to assist engineers in the design and evaluation of crewstations for Naval Systems. A fundamental step in the design process involves the allocation of panel space to aircraft subsystems and the determination of a physical arrangement for those subsystems. An automated

procedure for accomplishing these tasks must be developed if the CAD Model is to become a viable design tool. CONSOLE will fulfill this requirement. The role of the CONSOLE program and it's relationship to the tasks performed by the crewstation or the subsystems designer is discussed in the following paragraphs.

The distinction between the crewstation designer and the subsystem designer should be noted. The crewstation designer has the responsibility of taking the parameter lists or individual subsystem panel layout sketches from the subsystem designers and incorporating them into the proper crew-station layout along with all the appropriate system requirements. It is generally his job to question the value of each of the displays or controls and to find out such things as the criticality and frequency of use of each. There are generally several subsystem designers for every crewstation designer. There may be one in charge of all aspects of several subsystems (e.g., electrical, hydraulic, etc.) or more often, one or more for each individual subsystem. It is their job to determine each of the particular subsystem parameters that should require display or control. They should also provide the rationale for the existence of the parameters displayed or controlled.

Both crewstation and subsystem designers must deal with many problems when developing a new crewstation configuration. Some of these problems include: What controls and displays are required? How large should this display be? Where should this control be placed? Can an existing control be used for this function or must a new control be developed? The designer, either crewstation or subsystem, must perform many complex tradeoffs in his efforts to effect an optimum compromise that will satisfy all system requirements. He often relies heavily upon his past experience in performing these tradeoffs. This reliance has been justified by a reduction in development costs since many time consuming decisions can be omitted for the new system development program. A limited reliance upon past experience may be prudent but an extensive reliance may actually produce negative effects by inhibiting required design changes and by perpetuating faulty crewstation designs. Examples of such negative effects are illustrated in the following paragraphs.

In the first example, a subset of controls and displays from a prior system development program may be included in a new configuration even though the controls and displays are no longer required. The designer cannot make significant contributions to the development process when changes in crewstation design fail to keep pace with the changing information requirements of advanced aircraft. If a designer borrows too extensively from his past experience, he may not realize that the requirements for a new system have changed. In this case, reliance upon past experience will function to inhibit design changes.

In a second example, one or more of the controls and displays from a prior system may have been ill suited to the older system. The poorly designed equipment may have been detected in the test and evaluation phase of the procurement cycle but were left unchanged due to the extreme cost of a retrofit and to the proven adaptability of the pilot population. A designer relying upon his past experience may use the same faulty equipment in a new system development program. Thus, he will actually perpetuate a crewstation design error that has already been identified.

The crewstation designer must also deal with another problem. That is, what to do with new instruments that have been developed to meet the changing information requirements of advanced aircraft. There are at least two pitfalls here. First, the newly developed equipment may simply be added to a growing list of controls and displays even though the information it contains is partially or totally redundant with information provided by existing instruments. In this case, the designer will be wasting limited panel real estate by an unnecessary duplication of hardware. On the other hand, established controls and displays may be discarded to accommodate a new piece of equipment which is assumed to perform the same function. In reality, the new equipment may only partially replicate the function of the discarded controls and displays. In this case, the designer has unwittingly sacrificed a required function in his quest to economize the available panel space.

A possible third pitfall is that of allocating space and positional priority to displays and controls that are indeed required from previous systems. Whereas there may be several reasons to keep the same relative configuration, the decision cannot be based solely on their use in the previous system. As newer systems evolve the priorities for use of display and control parameters tend to change. Accordingly their space and position assignments should be re-evaluated.

In view of the heavy recall requirements and the complexity of the tradeoffs that must be performed, it would not be surprising if the crewstation designer were unable to describe the methods he used during the design development process. Such a lack of accountability has several negative implications for the overall system development program. In the absence of an explicit record of the tradeoffs, assumptions and recall of information from prior efforts, the crewstation designer may be unable to defend his recommendations. Thus, the credibility and the importance of his inputs to the system development program may be seriously questioned.

CONSOLE is being developed to help crewstation designers cope with the traditional design problems discussed above. CONSOLE will facilitate the design development process in the following ways:

(a) It will reduce design time by automating many routine tasks. Thus, the designer will be able to devote a greater proportion of his time to the complex tradeoff decisions that must be performed.

(b) It will reduce demands upon the designer's immediate memory by keeping track of many complex interrelationships among the controls and displays of all aircraft subsystems.

(c) It will provide a systematic approach to the panel layout problem that will enable the designer to discover his errors more rapidly and to initiate design modifications more easily.

(d) It will provide the designer with an explicit record of the design decision process.

6.2 CONSOLE Design Objectives

The primary objectives of the CONSOLE Model are to design a computer program that will:

(a) allocate panel space to major aircraft subsystems or related control/display functional groupings according to some rational and equitable objective functions,

(b) arrange aircraft subsystems on a panel in such a way as to maximize their usefulness, thereby insuring that all mission objectives may be accomplished in an efficient manner,

(c) have a simple user interface requiring a limited number of inputs and having a great deal of flexibility with regard to input format,

(d) insure a high degree of involvement in the design decision process by the crewstation designer,

(e) generate both tabular and graphical outputs useful to the crewstation designer.

CONSOLE is being developed as a subprogram of the CAD Model. By utilizing several existing features of the CAD software, (e.g., coordinate conversion routines, CAD element dictionary, scaling routines, etc.) it is believed that all of the objectives listed above can be successfully accomplished.

6.3 The CONSOLE Concept

The primary idea behind the CONSOLE Model is that all good panel layout designs must incorporate certain basic characteristics. CONSOLE represents

AD-A033 856 BOEING AEROSPACE CO SEATTLE WASH F/G 9/2

COMPUTER AIDED FUNCTION-ALLOCATION EVALUATION SYSTEM (CAFES).(U)

MAR 76 R E EDWARDS, K S RENSHAW, M J HEALY N62269-75-C-0239

UNCLASSIFIED D180-19338-1 NL

2 OF 3

AD

A033856

an attempt to define these characteristics and to integrate them into a computer model that can be systematically applied to crewstation design problems. The following paragraphs discuss several aspects of the CONSOLE Model that are crucial considerations for any automated panel layout procedure.

6.3.1 Accessibility

One critical consideration concerns the accessibility of various locations within a crew workstation. Obviously, the most important controls and displays should be placed in the most accessible locations. The accessibility problem can be solved by partitioning the available panel space into several zones. A zone that is located directly in front of an operator and in the center of a panel will generally be more accessible than any other area on the panel. Therefore, the most centrally located zone is given the highest priority rating. The priority assigned to a zone decreases as the distance between the zone and the center of the panel increases. Side panels and panel space behind an operator are given the lowest priority ratings. This zoning procedure enables the model user to deal with the relationship between an instruments accessibility requirements and its location upon a panel.

6.3.2 Balance of Real and Ideal

CONSOLE will provide the crewstation designer with two types of panel layouts; an idealized layout design and a pragmatic, or realistic, layout design. The goal of the idealized layout will be to optimize both the size and the spatial location of subsystem controls and displays. The optimization routines used to generate such layouts, however, are often insensitive to realistic design constraints and requirements such as standards for the size and shape of controls and displays and the alignment of controls and displays with supporting structures behind the panel. Therefore, the idealized panel layout model must impose some type of restriction upon the size and shape of the computer generated controls and displays. These restrictions might include the following: no control or display shall be allocated a surface area that is smaller than a specified minimum area; no control or

display shall be allocated a surface that is larger than a specified maximum area; and all controls and displays will be rectangular in shape. A computer model without such restrictions will generate panel layouts in which many controls and displays are characterized by complex geometric shapes and/or unrealistic sizes. Even with these restrictions, however, the amount of space allocated to controls and displays by the idealized model will generally differ from the size of existing controls and displays.

Since we do not generally have this much flexibility in the real world, a more realistic, or pragmatic, layout design must also be generated. Outputs of the pragmatic model will be constrained by the use of existing military standards for the shape and size of all controls and displays and by arranging the controls and displays so that they are aligned with the structural supports behind the panel. Thus, the pragmatic model will be more concerned with optimizing the spatial relationships among all functional groups of controls and displays than with optimizing the amount of space that is allocated to the functional groups. By having both types of layout designs, the designer can use the idealized layout to obtain valuable information concerning panel design tradeoffs that must be made for incorporation into the realistic layout design.

6.3.3 Functional Grouping

Another important consideration concerns the interrelationship between various aircraft subsystems. A superior panel layout should minimize the distance traveled by both hand and eye in performing a sequence of tasks and also minimize the time required to perform the sequence of tasks. To achieve these goals, an automated panel layout procedure must consider the interrelationships between all aircraft subsystems. If workloads are to be minimized, subsystems that are highly related to one another must occupy adjacent locations on a panel. This same principle also applies to individual controls and displays.

6.3.4 Criticality, Utilization and Information Transfer

A fourth consideration involves several attributes that are shared in common by all controls and displays. Every control and display can be described in terms of its criticality, frequency of use, and the amount of information it transmits to an operator per unit of time. Both the amount of panel space allocated to a control or display and the location of the control or display upon a panel should be a function of these three primary characteristics. As a general rule, displays and controls that are highly critical for flight safety and for mission success should be given a greater proportion of the panel space and/or should be located in the most accessible areas. In a similar manner, controls and displays that are used most frequently and that transmit the most information per unit of time should also be given a greater proportion of the panel area and/or should be placed in the most accessible areas. It should be noted that the values assigned to the information transfer characteristic will vary considerably from one display to another. The information transfer characteristic should be defined in such a way as to handle the distinction between multifunction and single function controls and displays and between controls and displays that operate in a continuous as opposed to a discrete manner.

Upon closer examination, it soon becomes apparent that all controls and displays do not possess equal degrees of each of the three characteristics. That is, a particular display may be monitored quite frequently even though it has a relatively low rate of information transmission and is only moderately critical for flight safety. From this example, it is clear that the three characteristics must be combined in some manner in order to determine the appropriate panel location and the amount of space that should be allocated. Thus, some type of an objective function is required to determine the relative contribution of the three characteristics.

6.3.5 Military Specifications and Standards

The automated panel layout procedure must generate configurations that are consistent with the restrictions imposed by military specifications and

military standards. Hence, the user must have some method by which he can specify mandatory, as well as desired, locations for the placement of controls and displays.

6.4 CONSOLE Input Requirements

CONSOLE will be used to assist the crewstation designer in the development of preliminary crewstation configurations. From CONSOLE, the designer will obtain an initial estimate of the amount of space that should be assigned to various aircraft subsystems (e.g., fuel management, engines, navigation, communications, weapons management, sensors, etc.) and a scheme for the spatial organization of the subsystems upon a panel. The following paragraphs describe the tasks that must be performed by the crewstation designer in order to prepare the inputs required by the CONSOLE Model.

A small number of inputs will be required to execute the CONSOLE Model. First, a crewstation workspace must be defined by providing two-dimensional coordinates (all in the same local coordinate system) for the following geometric items: the entire surface area of the panel that is available for control/display placement; all structural supports for mounting items on the panel; and all zones of differing priority on the panel. Then, the acceptable shapes and sizes for all functional groups must be defined by providing the two-dimensional coordinates for all standard military panel units (that are separate functional entities) that are to be considered for the problem. All controls and displays to be placed on the total CONSOLE panel area must be identified and assigned to a functional group.

The following information must be provided for each control and display: the two-dimensional coordinates; a criticality rating; a frequency of use rating; a functional group assignment, and an estimate of the amount of information it transmits. The criticality score will be obtained by evaluating each control or display against a five-point scale. The rater will assume that each successive control or display has ceased to function and will then select one of the following criticality scores: (5) Flight safety is lost; (4) Mission must be aborted; (3) Flight safety and/or mission

success will be degraded; (2) Alternative techniques must be used and/or there will be an increase in crew workload but without degradation of flight safety or mission success; and (1) The failure has no effect. Each of the criticality scores is used as a weighting factor in the determination of a panel space allocation. It should be noted that the exact relative weight of each criticality score, or number, has not as yet been determined. As the program receives more use, a more accurate determination of these relative values will be made. The frequency of use rating will be obtained by estimating the percent of the mission time that the particular control or display will be used. The amount of information transmitted by a control or display will be represented by an integer number, with larger numbers indicating greater amounts of information transmission. The magnitude of the information transmission score will be greater for multifunction than for single function controls and displays and for controls and displays that operate in a continuous manner. Whereas the quantity of BITS in a discrete display or control is easily determined, the quantification of information transmission for continuous displays or controls is much more difficult. It has been suggested that 4 bits be used as an average value for continuous displays and controls. Additional effort needs to be made to determine the best method of quantifying continuous information transmission.

Finally, the following information must be provided for each function group: the group name; the two-dimensional coordinates for the group; restrictions on geometric placement with mandatory locations defined by the two-dimensional coordinates for the centroid of the group and with desired locations defined by a zone number; and the degree of relationship to other functional groups with a one (1) defining a high degree of relationship and a two (2) defining a moderate degree of relationship.

Figure 16 illustrates the CONSOLE input format for a set of hypothetical data. It should be noted that the coordinates specified in the STRUCTURAL SUPPORT DATA section and in the ZONE DATA section are in terms of the CONSOLE coordinate system. The coordinates specified for each functional group are in terms of the appropriate coordinates in the ZONE DATA section while the coordinates associated with specific controls and displays are in terms

```
CONSOLE COORDINATES =  0,0  30,0  30,25  0,25/
STRUCTURAL SUPPORT DATA/
     1 =  0,0  1,0  1,25  0,25/
     2 = 10,0 11,0 11,25 10,25/
     3 = 20,0 21,0 21,25 20,25/
     4 = 29,0 30,0 30,25 29,25/
ZONE DATA/
     4A =   0,0  10,0  10,25   0,25/
      3 =  10,0  20,0  20,10  10,10/
      1 =  10,10 20,10 20,20  10,20/
      2 =  10,20 20,20 20,25  10,25/
     4B =  20,0  30,0  30,25  20,25/
STANDARDIZED PANEL DATA/
     1 =  0,0  10,0  10,2  0,2/
     2 =  0,0  10,0  10,3  0,3/
     3 =  0,0  10,0  10,4  0,4/
     4 =  0,0  10,0  10,5  0,5/
     5 =  0,0  10,0  10,6  0,6/
FUNCTIONAL GROUP = ENGINE SUBSYSTEM/
     COORDINATES =  0,0  10,0  10,6  0,6/
     PLACEMENT = ZONE 1/
     RELATIONSHIPS = THROTTLE (1)/
     DISPLAY DATA/
          NAME = RPM/
               COORDINATES =  0,0  2.5,0  2.5,6  0,6/
               CRITICALITY = 3/
               FREQUENCY = 35/
               INFORMATION = 2/
          NAME = TURBINE OUTLET PRESSURE/
               COORDINATES = 2.5,0  5,0  5,6  2.5,6/
               CRITICALITY = 4/
               FREQUENCY = 50/
               INFORMATION = 2/
          NAME = TURBINE OUTLET TEMPERATURE/
               COORDINATES = 5,0  7.5,0  7.5,6  5,6/
```

Figure 16. CONSOLE Input Format

```
            CRITICALITY = 4/
            FREQUENCY = 50/
            INFORMATION = 2/
        NAME = FUEL FLOW/
            COORDINATES = 7.5,0  10,0  10,6  7.5,6/
            CRITICALITY = 1/
            FREQUENCY = 25/
            INFORMATION = 2/
FUNCTIONAL GROUP = PRIMARY ATTITUDE INDICATOR/
    COORDINATES = 0,0  10,0  10,4  0,4/
    PLACEMENT = 15,18/
    RELATIONSHIPS = ALTIMETRY SUBSYSTEM (1), AIRSPEED SUBSYSTEM (1)/
    DISPLAY DATA/
        NAME = ATTITUDE INDICATOR/
            COORDINATES = 0,1  10,1  10,4  0,4/
            CRITICALITY = 5/
            FREQUENCY = 75/
            INFORMATION = 3/
    CONTROL DATA/
        NAME = CONTRAST SELECTOR/
            COORDINATES = 0,0  3.33,0  3.33,1  0,1/
            CRITICALITY = 1/
            FREQUENCY = 5/
            INFORMATION = 1/
        NAME = BRIGHTNESS SELECTOR/
            COORDINATES = 3.33,0  6.66,0  6.66,1  3.33,1/
            CRITICALITY = 1/
            FREQUENCY = 5/
            INFORMATION = 1/
        NAME = MODE CONTROL/
            COORDINATES = 6.66,0  10,0  10,1  6.66,1/
            CRITICALITY = 1/
            FREQUENCY = 15/
            INFORMATION = 1/
```

Figure 16. CONSOLE Input Format (cont.)

of the FUNCTIONAL GROUP coordinates. When a functional group must be placed in a fixed location on the console (as the primary attitude indicator in this example) the coordinates for the centroid of that group are specified in terms of the appropriate coordinates in the ZONE DATA section.

6.5 CONSOLE Computing Functions

6.5.1 Allocation of Panel Space

The CUBITS concept developed by CDR R. J. Wherry, Jr., NADC, will be used for the panel space optimization function of the CONSOLE Model. The CUBITS concept is based upon the characteristics that are shared by all controls and displays: criticality, frequency of utilization and amount of information transmitted (BITS). The optimal amount of space that should be allocated to a control or display can be obtained from the CUBITS formula: Space = Criticality X Utilization X BITS. Since the initial CONSOLE Model will deal with groups of controls and displays that are functionally related, the CUBITS scores calculated for each control and display within the functional group must be summed. The CUBITS scores will then be summed over all of the functional groups. The optimal percent of the panel space allocated to a functional group will be calculated by dividing the CUBITS score of each functional group by the sum of the CUBITS scores for all functional groups. The optimal area, in terms of panel space, for each functional group will then be calculated by multiplying the percent of the panel space allocated to each functional group by the total surface area of the panel.

The CONSOLE computing routines will then calculate the area for each functional group from the group's coordinates. If the amount of space allocated to a functional group by the CUBITS formula is greater than the existing full scale area of the group (assuming a design for the group already exists), the full scale area will be used in the CONSOLE plotting routines. If the amount of space allocated to a functional group by the CUBITS formula is less than the existing full scale area of the group, CONSOLE will select the smallest standard panel from the STANDARDIZED PANEL DATA section that will accommodate the CUBITS area allocated to that group. With this procedure,

the computer-generated shape assigned to each functional group will always be user defined. Therefore, CONSOLE will avoid the problems encountered by other area optimization routines that fail to maintain shape conservation as areas are changed.

6.5.2 Spatial Arrangement of Functional Groups

After optimizing the area allocated to each functional group, the program flow will transfer to the spatial arrangement optimization routines. These routines simply consist of a set of rules for processing the functional groups. A preliminary spatial arrangement optimization routine is shown in the flow diagram in Figure 17. As can be seen, the sequence by which functional groups will be processed is based upon several considerations. A few of these considerations are illustrated by the following questions: Which group has the largest surface area? Was a mandatory location specified for this group? Is this group related to another group that is already on the panel? Has a desired location been specified for this group? As can be seen in Figure 17, the processing rules can become very complex. Despite their complexity, such logic diagrams have several advantages. First, they provide an objective record of the rationale behind many design decisions. Furthermore, they are open to examination and can be easily modified.

In addition to the specific processing rules shown in Figure 17, a small number of more general rules will also be included in the spatial arrangement optimization routines. The following examples illustrate the nature of these rules: No group shall overlap a panel boundary; all panels must be aligned with their supporting members; two panels cannot occupy the same space on a panel; if no mandatory or desired location is specified and the group is not related to another group that is already on the panel, place the group as far forward (up) as possible and then as close to the center of the total CONSOLE area as possible.

6.6 CONSOLE Outputs

CONSOLE will produce both graphic and tabular outputs. Tabular output will include an alphabetized listing of all functional groups and of all controls and displays that are contained in each functional group and an alphabetized

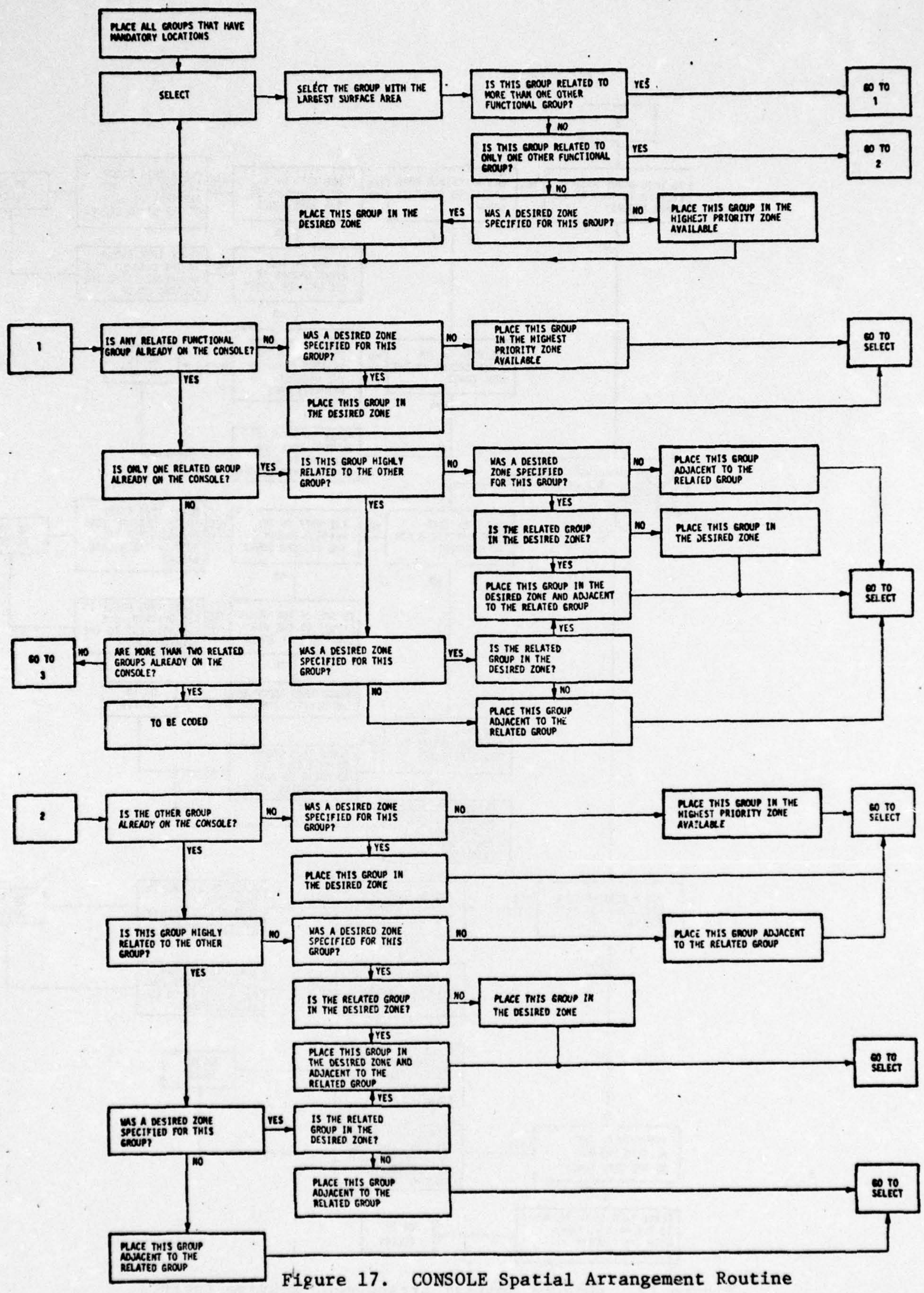

Figure 17. CONSOLE Spatial Arrangement Routine

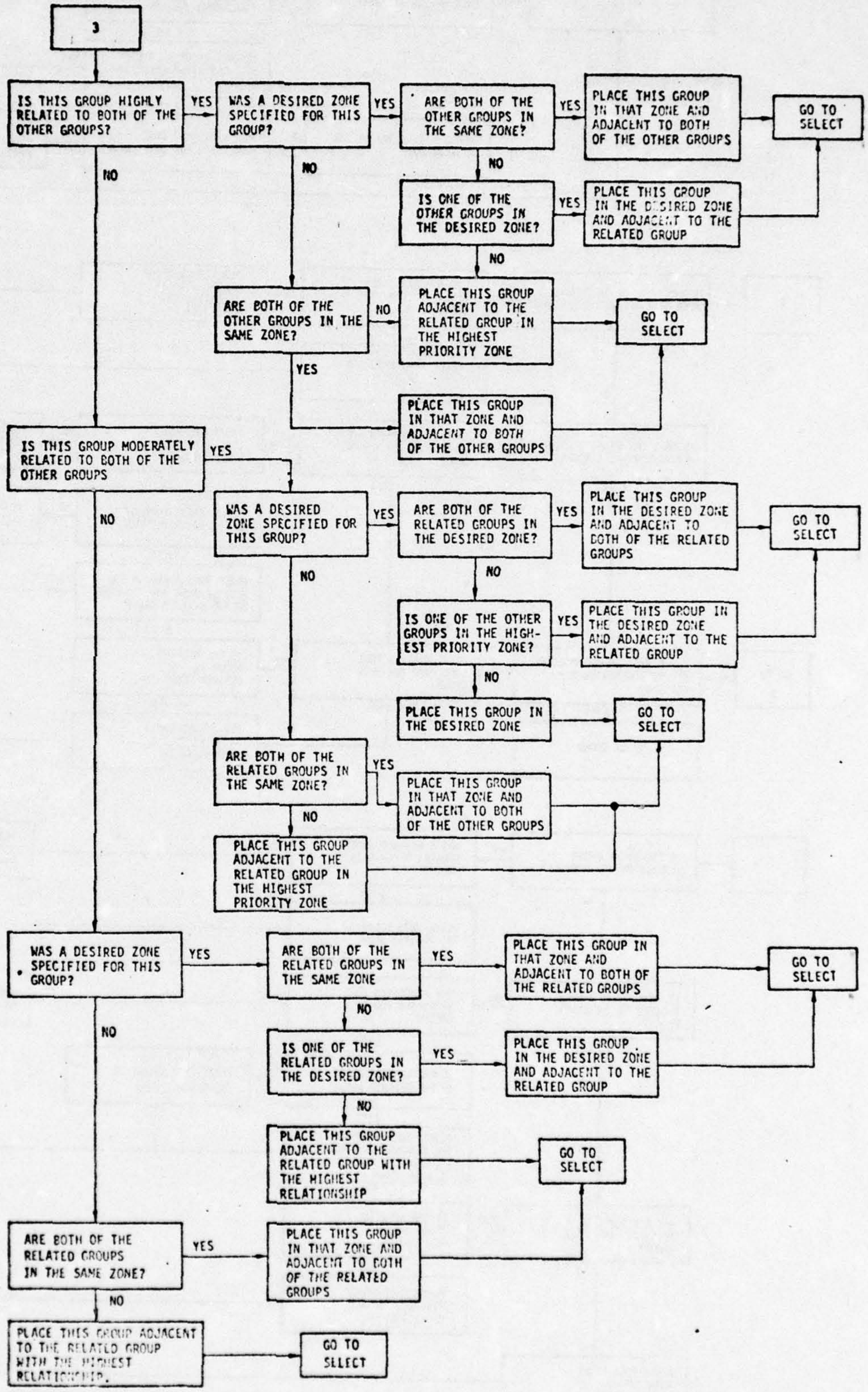

Figure 17. CONSOLE Spatial Arrangement Routine (cont.)

listing of all controls, displays and functional groups that are contained in each zone on the panel. CONSOLE will also provide a table that contains both the existing full scale surface area and the CUBITS generated raw score of the optimized surface area for all controls, displays and functional groups. Finally, an alphabetized list will be provided for all controls and displays that exceed a predetermined CUBITS raw score and that have been placed in a low priority zone.

Graphic outputs will be provided for both an idealized and a pragmatic console layout design. Both layouts will clearly illustrate the optimal spatial relationships between all functional groups. In addition, the optimized panel space allocated to each functional group will be shown in the idealized layouts. Both the amount of space allocated to a group and it's location upon the panel will be a direct result of the user specified parameter values that are input to the optimization routines. As long as the values assigned to the optimization parameters remain the same, CONSOLE will continue to output the same optimized layout design. A unique series of optimized configurations can be produced by simply altering the value of one or more of the optimization parameters. Since many different panel configurations can be generated, the designer will retain ultimate responsibility for making design decisions. He will select the most promising layout for further development and perform the necessary tradeoffs to insure that all system requirements will be met. As a result of these tradeoffs, the designer may decide to change the size, shape or location of several controls and displays to create the final panel layout.

7.0 CAFES VALIDATION AND IMPLEMENTATION PLANS

A preliminary plan for CAFES validation and implementation was developed during the CAFES Phase IV Program (Reference 8). The separate implementation and validation plans, as they relate to the Phase VI Program, will be discussed in the following section.

7.1 Implementation Plan

The Phase VI implementation plan will include the following activities:

(a) A phased delivery of all CAFES submodels to the NADC computing facility at Johnsville, Pennsylvania and the installation of those models on the NADC 6600,

(b) Verification tests to insure that all of the submodel computing functions are operating properly,

(c) Presentation of a training course to acquaint NADC personnel with the CAFES submodels,

(d) Establishment of a CAFES Center at NADC.

The first three items are discussed in the CAFES Phase VI Program Plan, of this document.

Effective utilization of the CAFES programs will be contingent upon the commitment, by NADC, of dedicated personnel to a Center for CAFES operations. The overall goal of the proposed Center will be to encourage application of the CAFES submodels to ongoing projects at NADC. The CAFES Center should be staffed by full time personnel who are well versed in CAFES operations including: input preparation; output interpretation; system development applications; availability of input data; previous run history; current system status; etc. The Center should function as a self-perpetuating program for training of all potential NADC users, for consultation of individuals lacking expertise on CAFES capabilities, and for performing all CAFES data

processing tasks. A systematic procedure should also be established for maintenance and updating of the CAFES software.

A full set of user and programmer documentation will be available at the CAFES Center. Additional documentation concerning potential areas of application for CAFES should also be available. These documents include the Human Factors Engineering Analytic Process Definition and Criterion Development for CAFES (Reference 6) and CAFES Applications in Ship Systems Development (Reference 7).

7.2 Validation Plan

Since delivery and installation of CAFES is anticipated during the Phase VI Program, the CAFES submodels will be implemented before they are validated. This sequence of events is consistent with the typical evolutionary development of most computer programs. In fact, it is only through implementation that a program becomes validated. Therefore, the validation concept will be considered in the context of CAFES implementation.

Specific plans for validation of the FAM and the WAM submodels were developed during the CAFES Phase IV Program. In these plans, the validity of each submodel was to be evaluated in terms of its fidelity, or correspondence to the "real world" and its utility, or contribution to the solution of practical problems. During Phase VI, validation efforts will only be directed toward an evaluation of the utility of the CAFES submodels. This is not to say that the fidelity concept is no longer important but that it is more important to establish the utility of a model before examining its fidelity. If it is found that a model does not contribute to the solution of practical problems, it does not matter whether the model corresponds to the "real world" or not. Thus, only after establishing the utility of a model does it become necessary to evaluate the fidelity of the model.

Data relevant to the utility question will be obtained by trial applications of the CAFES submodels to practical problems. Possible sources of application include ongoing system development projects and programs where long range forecasting of requirements are being made

for advanced systems. These applications should reveal any inadequacies in the CAFES software and should also provide valuable information concerning additional capabilities or refinements that may be required.

8.0 RESTRUCTURE OF CAFES DOCUMENTATION

The CAFES User's Guide has been under evolutionary development since the completion of Phase IB in 1972. During this time, both user and programmer documentation were developing rapidly to keep pace with new software developments. The size and the complexity of the user documentation has continued to increase with each new developmental phase. As a result of these changes, retrieval of information from the CAFES documents has become increasingly difficult. This problem has arisen because most of the CAFES submodel programs have spanned several developmental phases. Thus, information on a particular model may be found in several different CAFES documents.

Initial efforts were made, during Phase IV, to improve the user interface by eliminating the demand for extensive cross referencing to information contained in preceding CAFES documents. To accomplish this, a detailed summary for each of the CAFES submodels was prepared by selecting material from the preceding developmental phases. Specific information about subsystem concept definitions, design features and operations, inputs, outputs and applications was integrated within each submodel summary. Restructuring of documentation continued during Phase V in anticipation of submodel delivery and installation during the Phase VI Program.

The previous efforts to modularize and integrate the CAFES documentation will be extended by the creation of a separate User's Manual and a Programmer's Manual for each of the CAFES submodels. A preliminary organizational scheme for these manuals was developed and information from previous CAFES volumes relevant to the current organizational structure is being retrieved and updated. These manuals have been retained due to the tentative nature of their structure and to the continuing requirement for selective modification of the contents. However, copies of the manuals could be made available upon request.

The eventual plan for CAFES documentation is to produce a multi-volume set of documents. The complete set of documents will contain an executive level summary of the CAFES System, a general introduction to the CAFES System and a

detailed description of each of the CAFES submodels. The introductory volume will contain a top level discussion of the general requirements and system specifications for CAFES, a summary of the overall CAFES concept and a brief description of each of the CAFES submodels. A User's Manual and a Programmer's Manual will be prepared for the DMS, FAM, WAM, CAD, and the CAFES interface modules. (Format for the HOS documentation will be coordinated with Analytics Inc.). These volumes will include all of the detailed information required to understand and use the submodels.

The user documentation will include a discussion of the following items:

(a) the purpose of the model,

(b) appropriate problems for model application,

(c) how the model operates,

(d) all model inputs and outputs,

(e) sample data cases with interpretation of outputs,

(f) options of the model,

(g) a complete listing and explanation of all program-generated messages.

The programmer documentation will include a description of the following items:

(a) the scope and purpose of the model,

(b) computing system specifications (type of computer, operating system, compiler, peripherals),

(c) gross operational characteristics of the model (run times, core requirements),

(d) the structure, functional flow, data files and data flow of the model,

(e) use of COMMON storage,

(f) the special purpose, diagnostics, change procedures and testing for all subprograms of the model,

(g) listings of the source code for the model,

(h) an alphabetized glossary of all programming variables.

The introductory volume and each of the submodel volumes will be issued in the form of a three-ring binder to facilitate updating of the CAFES documentation as the models are modified in future developmental phases. The final documentation system is illustrated in Figure 18.

A concise Document Information Guide was also developed during Phase V to assist in the restructuring task and to relieve the information retrieval problem. The Guide indexes and cross references most of the information contained in the previous CAFES volumes. The Document Information Guide is contained in appendix H.

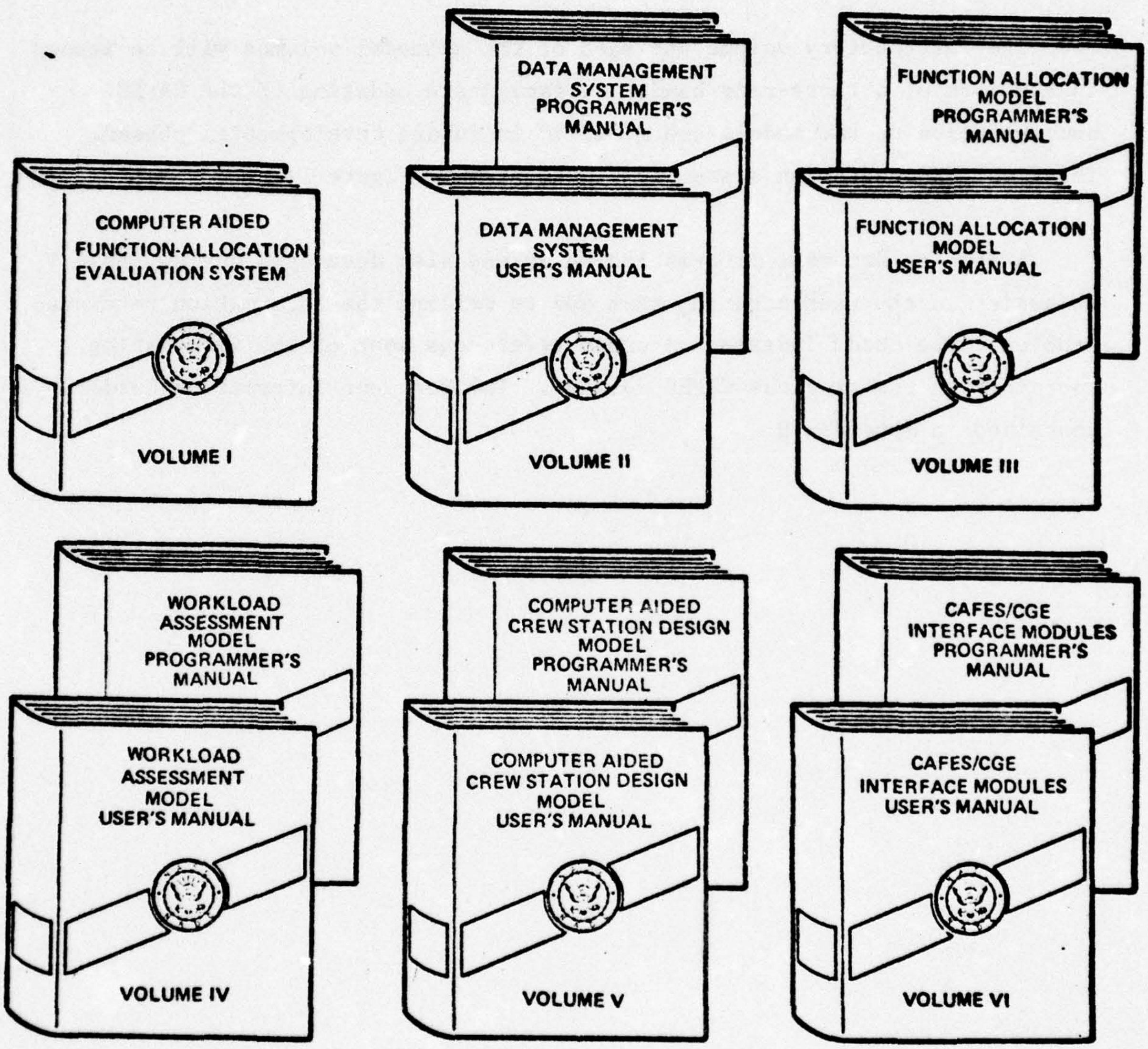

Figure 18. Final Documentation of the CAFES System

9.0 CAFES INTEGRATION PLAN

The primary goal of the CAFES integration plan is to integrate CGE and HOS into the CAFES system. These models are being emphasized for two reasons. First, neither CGE nor HOS was developed under the CAFES Program. CGE was developed by The Boeing Company during the period 1967 - 1971 while under contract to JANAIR. HOS is currently being developed by NADC. Secondly, all three of the computer systems would benefit by an active data exchange program. The CAFES submodels could provide CGE and HOS with required input data while CGE and HOS could be of value to CAFES by reflecting errors that may have been made in earlier stages of the system development cycle.

The initial efforts to integrate CGE into CAFES were begun during Phase IV of the CAFES Program and have continued during Phase V. The integration effort began with an examination of CGE inputs, outputs and processes to identify all potential data interfaces with the other CAFES models. Several data interfaces were identified and are summarized below.

INTERFACE NO. 1

CGE ↗ Crewstation Geometry ↘ CAD

Explanation: Crewstation geometry which has been input to CGE could be input directly to CAD from CGE for reach analysis, vision analysis, escape analysis, or for redesign purposes.

INTERFACE NO. 2

DMS ↗ Crewstation Geometry
Task Sequence Data ↘ CGE

Explanation: The free field format of CAFES could be used to input and store cockpit plane and control definitions and task sequence data in the DMS. Upon user command, a card deck containing the same data could be produced with a format identical to the inputs required by the CGE CDDATA and STORAGE models.

INTERFACE NO. 3

CAD → Crewstation Geometry → CGE

Explanation: Crewstation designs developed by CAD could be input directly to CGE to evaluate them for physical and visual interferences, compliance with military specifications and standards, or to generate perspective or sectional drawings of the crewstation.

INTERFACE NO. 4

CGE → Reach Envelopes → CAD

Explanation: Reach envelopes for various sized crewmembers and different seat positions generated by the CGE Reach Basket Model could be input directly to CAD for crewstation reach analyses.

INTERFACE No. 5

CGE → Escape Envelopes → CAD

Explanation: Escape envelopes for various sized crewmembers, seat back angles and seat positions generated by CGE could be input directly to CAD for escape analyses.

INTERFACE No. 6

WAM → Task Sequence Data → CGE

Explanation: Task sequences verified by WAM workload analyses could be directly input to CGE for motion interference analysis.

Three of these interfaces have already been developed. The first interface was developed during the CAFES Phase IV Program. The second and third interfaces were developed during Phase V and are described in this document.

Several changes to the DMS and to the CGE software were required to make CGE compatible with the CAFES Data Management System. These changes included the creation of new primary and secondary data categories within the DMS to receive input data required by CGE and the development of buffer routines for conversion of CAFES submodel data parameters into a format that would be consistent with CGE input requirements.

Integration of HOS into the CAFES system was begun during Phase V of the CAFES Program. The HOS integration effort began with a series of meetings which were held at the Boeing Aerospace Company to consider possible interfaces between the Human Operator Simulator and the other CAFES submodels. Representatives from the Naval Air Development Center, Analytics Incorporated, Boeing Aerospace Company and Boeing Computer Services participated in the discussions. It was concluded that the integrated CAFES system will generally be applied in two different problem areas; development of new systems and reevaluation of existing systems. For new systems development programs, the CAFES submodels will generally be applied in the following order: FAM; WAM; CAD; CGE and HOS. This order corresponds to the sequence of efforts normally performed by the HFE in new systems development programs. The system development cycle begins with a definition of mission requirements and progresses through the following stages: function allocation; task-workload analysis and finally, crewstation design and evaluation. Hence, a unidirectional forward feeding interface is implied in which data obtained from earlier developmental phases will be input, or will facilitate input, to later developmental phases.

The CAFES submodels will also be used to evaluate existing systems. Such applications might include the evaluation of alternative cockpit configurations or an evaluation of the impact on workload due to the addition of a new piece of equipment in a proven configuration. For these types of problems, the CAFES submodels will probably be used more or less independently. The selection of appropriate CAFES submodels will depend upon the following factors: how quickly an answer is needed; the degree of accuracy required and the amount of detailed information available for the system being examined. CGE and HOS would most likely be used when a great deal of

accruacy is required, when HFE decision time is not necessarily a critical factor and when detailed information about the system is available. FAM, WAM and CAD would be applied when the amount of detailed information and/or decision time is quite small or when a less sophisticated evaluation is adequate and the intent is to quickly identify and resolve gross problem areas before concepts are evolved to any large degree.

Given these constraints on the probable use of the CAFES submodels, the following interface modules were identified for possible future development.

INTERFACE NO. 7

FAM $\xrightarrow{\text{Operator Procedures Data}}$ HAL

Explanation: The Human Operator Procedures Language (HOPROC) could be used to describe all of the tasks in the task list from a FAM mission scenario. FAM would then produce a task timeline for each operator over the entire mission. The task timeline would be composed of operator procedure statements that could be used by WAM for workload evaluations and could also be augmented with additional HOPROC statements to provide the Operator Procedures input required by the HOPROC Assembler Loader (HAL). The basic advantage of this interface is that the task timeline provided by FAM would be based upon task reliability data. Thus, task reliability data would be indirectly incorporated into HOS.

A second benefit of the FAM/HAL interface is that the CAFES models could take advantage of the high degree of precision and consistency of terminology that is inherent in the HOPROC language. The word, task, for example, has been used rather freely in the CAFES documentation. Inconsistencies in the level of detail used to describe a task sequence soon become apparent when the work, task, is equated with such activities as grasping a control (micromolecular level), changing a control setting (molecular level) and performing a series of turning maneuvers (molar level). Such a cavalier use of terms is counterproductive to the stated goals of CAFES. The standardization of terminology gained from the HOPROC language would also enable the CAFES user to prepare input data more rapidly and to track the data more easily from one model to another.

INTERFACE NO. 8

CAD → Control, Display and Setting Data → HAL

Explanation: An interface could be developed between CAD and HAL that would generate input data for the DISPLAY, CONTROL and SETTING sections required by HAL. These sections contain information such as the title and type of each device, scale factors, scale settings and device coordinates. This information could be placed in the CAD data bank during the data digitization process. The basic advantage provided by the CAD data bank is that a built-in cross-referencing system is thereby created between the aircraft coordinate system and the information contained in the DISPLAY, CONTROL and SETTING sections. With this interface, it would be possible to obtain panel plots and tabular listings showing all devices and their associated characteristics for each panel. Thus, this interface could be used to perform data verification and checkout of HAL input data.

INTERFACE NO. 9

CAD → Crewstation Coordinates → HOS

Explanation: A data digitizing capability could be developed to provide the three-dimensional coordinates for all individual controls, displays and symbols as well as overall crewstation layouts that are required as direct inputs to HOS. The CAD submodel could transform the digitized data for individual controls, displays and symbols into an appropriate coordinate system and output the coordinates to a permanent file. The data on this file would contain blank fields in locations that require unique inputs to HOS (i.e., device model number, hab strength, criticality, etc.). This file could be merged with a similar file containing the unique HOS inputs. The merged file could then be input directly to HOS. The advantage of this interface is that the user would not be required to manually obtain, code and keypunch the three-dimensional coordinates required by HOS.

Despite the unidirectional nature of the HOS/CAFES interfaces identified above, it should be noted that outputs from HOS will be useful to the CAFES

submodels in at least two respects. First, HOS can be used to generate performance times of specific tasks for which empirical data are not available. The HOS generated performance times could then be used in future FAM and WAM analyses involving those tasks. Secondly, workload problems revealed by HOS outputs will lead to modification of the basic function allocation and/or crewstation design assumptions that were made in earlier phases of the system development cycle.

The final suggestion for a HOS/CAFES interface deals with a need for consistency of terminology in the sample problem documentation for all of the CAFES submodels. This need could be satisfied, to a large extent, by the selection of a standard problem for analysis. Such a problem would help an unfamiliar user understand the relationship between the inputs required by the different submodels. This type of integration effort would also facilitate interpretation and application of submodel outputs by allowing the user to readily compare and correlate the inputs and outputs of one submodel with the inputs and outputs of another submodel.

10.0 CAFES PHASE VI PROGRAM PLAN

Most of the CAFES effort during the past five phases has been directed toward concept formulation and software development of a number of computer-aids for the HFE community. Until now, each of the CAFES computer models has been primarily used in a research and development environment. During the Phase VI Program, however, major emphasis will shift from software development to software refinement and documentation in anticipation of routine production runs following delivery and installation at NADC. The successful transition from a research and development level to a production level is contingent upon completion of the following tasks:

(a) Complete Submodel Integration,

(b) Complete Submodel Efficiency Improvements,

(c) Complete User Interface Improvements,

(d) Complete System Documentation,

(e) Complete CAD Developments,

(f) Prepare CAFES Training Course Materials,

(g) Establish Configuration Control System and Procedures,

(h) Deliver and Install CAFES at NADC.

Each of these tasks will be discussed in the following paragraphs.

10.1 Complete Submodel Integration

Integration of the CAFES submodels will require work in two areas. The first area involves the development of interface modules between the CAFES submodels. As noted in the CAFES Interface Plan of this document, the primary goal of the integration effort will be to develop several interface modules

between CGE and the CAFES submodels and between HOS and the CAFES submodels. The specific interface modules to be developed are discussed in the CAFES Interface Plan.

The second integration area involves the identification of all direct data interfaces between the CAFES submodels. Two types of data interfaces will be defined: direct and indirect. A direct data interface will refer to an exchange of data between models that does not require user intervention. In an indirect data interface, the user will mediate the data exchange by using outputs of one model to guide his judgment in preparing inputs to another model. Specific data interfaces for FAM, WAM and CAD were identified during Phase IV. This effort will be extended to include the DMS, the CAFES/CGE interface modules and the CAFES/HOS interface modules.

10.2 Complete Submodel Efficiency Improvements

Several tasks are included under the category of submodel efficiency improvements. Perhaps the most important task will be program debugging as the models undergo final verification testing. A greater number of verification tests will be required for the FAM and CAD submodels since they have been executed less frequently than the WAM. In addition, minor software improvements will be made to enhance specific model capabilities as blocks of inefficient coding are discovered. Two such areas for improving specific model capabilities have already been identified for the DMS. First, the total compilation time required to remove data input errors could be reduced if the user were allowed to discover many data input errors in a single job submittal. This could be achieved by modifying the CAFES executive and data editors so that they would be able to recognize a valid input statement that immediately follows an invalid statement. With this modification, program compilation would continue following improper data input and would expose a greater number of errors in the input data.

A second DMS efficiency improvement could be obtained by preventing erroneous input data from being executed. Only after all errors in the compilation phase are discovered and corrected should program execution be allowed to continue. Therefore, the overall efficiency of the CAFES submodels

could be improved if the DMS executive was modified to preclude program execution following a data input error.

Additional software improvements have been identified for the CGE Reach Basket Model. A discussion of these efficiency improvements is contained in this document.

10.3 Complete User Interface Improvements

The user interface is directly affected by such factors as the preparation of data inputs, interpretation of data outputs and the amount and kind of error diagnostics that are provided. During earlier CAFES Phases, major emphasis was placed upon concept formulation and software development with relatively little attention toward optimization of the user interface. Hence, transition of the CAFES models to a production level system will require a large number of user interface refinements.

One set of refinements will involve modification of the CAFES data editors. When a data input error is recognized by the CAFES data editors, the error is flagged with an error number on the user's output. The user must then determine the meaning of the error number by referencing a table of error messages. Timely interpretation of data input errors would be enhanced by storing all error descriptions in the DMS data bank. The CAFES error diagnostic software could then be modified to provide the following information each time a data input error is encountered: the error number, the current value of all relevant variables and an English language description of the error.

A second set of user interface refinements will be directed toward improving the interpretation of CAFES outputs. At the present time, many of the submodel output reports are quite cluttered and require extensive user familiarity for interpretation. This is especially true for many of the FAM and CAD output reports. The interpretation of model outputs can be significantly improved, in most cases, by a reorganization of tabular outputs and by a judicious selection of data parameter names. These changes will be accomplished through the selective modification of software routines in the DMS report generator and of parameter names in the submodel data categories.

10.4 Complete System Documentation

Both the user interface and the programmer interface with the CAFES submodels will be significantly improved by completion of the CAFES User's Guide and Programmer's Guide. These volumes will contain extensive documentation concerning the scope of each model, potential areas of application, model assumptions, sample data cases, input requirements, output formats and an explanation of the user's role in CAFES applications. Documentation will also be included for all new model developments, submodel integration and submodel efficiency improvements that are completed during the Phase VI Program. Further information concerning the CAFES System documentation can be found in the RESTRUCTURE OF CAFES DOCUMENTATION section of this document.

10.5 Complete CAD Developments

Completion of all CAD submodel developments will require work in four basic areas. First a number of tasks must be performed to refine the CAD capabilities that were initiated in Phases III and IV. The following tasks are included in this category:

(a) Develop the capability for the cockpit scaling subroutine to perform differential scaling of cockpit geometry. At the present time, only uniform scaling of cockpit geometry can be performed,

(b) Develop the capability for production of Calcomp 3-view plots that will provide front view, top view, side view and axonometric views of crewstation geometry,

(c) Develop the capability for user specification of the scale factor for output of panel plots,

(d) Modify the crewstation tailoring module to provide for easier crewstation geometry updates.

The second set of CAD development tasks will focus upon the CAD reach analysis module. In the current reach analysis module, a laborious manual procedure is required to prepare the reach analysis input data. Useability of

the reach analysis module would be greatly increased if the reach envelope data were automatically generated and input to the CAD reach analysis module. This refinement will require a trade study and the development of a new CAFES interface module. The trade study will be performed to evaluate the relative merits of using the CGE Reach Basket Analysis versus the Crewstation Assessment of Reach (CAR) Model to generate reach envelopes that can be input directly to CAD. Based upon the outcome of the trade study, an interface module will be developed to allow for input of reach envelopes to the reach analysis module.

The third set of tasks will continue development of CONSOLE, the optimized panel space allocation program. Design guidelines and general functional requirements for CONSOLE were developed during Phase V and are contained in this document. The detailed software design and software development tasks will be performed during Phase VI. These tasks will include flow charting, coding and software verification for the preliminary CONSOLE specification.

The final CAD objective will be to develop a stand alone data digitizing program and to incorporate that program into the CAD editor. With this program, digitized data could be stored on a tape or disk file and automatically accessed by CAD for execution of the CAD subprograms. Several advantages of the data digitizing procedure were demonstrated during Phase IV. The data digitizer, when combined with a computer terminal that will allow interpolation of alphabetic characters within a string of numeric characters, was found to be a versatile tool, with its speed and accuracy far exceeding that obtainable by manual methods.

10.6 Prepare CAFES Training Materials

A training course on CAFES operations will be presented to NADC personnel following installation of CAFES at NADC. Development of the training course will entail preparation of instructional materials, visual aids and sample problem exercises. The training course will include classroom problem solving experience via preparation of data input cases, execution of the CAFES submodels and interpretation of model outputs.

10.7 Prepare Softward Delivery Package

Preparation of the NADC software delivery package will be coordinated with personnel from NADC and from SAMA Division-Eastern Operations in Falls Church, Virginia. Specific tasks will include:

(a) Definition of computer systems at BCS and NADC,

(b) Definition of a baseline source code configuration and an implementation subset,

(c) Development of a benchmark data set containing cases to comprehensively test the code,

(d) Establishment of an implementation software configuration at SAMA Division Eastern Headquarters/NADC,

(e) Execution of the implementation code against the benchmark data set.

10.8 Establish Configuration Control System and Procedures

A configuration control system and a set of configuration control procedures must be established prior to delivery and installation of CAFES software. The configuration control system and procedures will provide a systematic method by which to maintain and update the NADC CAFES configuration. Thus, the system will provide for technical consultation and software maintenance related to operation and use of the NADC configuration and, at the same time, allow for new CAFES developments and modifications to existing software routines without interrupting CAFES operations at NADC.

10.9 Deliver and Install CAFES at NADC

Delivery and installation of the CAFES software will be coordinated with NADC personnel and with SAMA Division-Eastern Operations personnel. The installation procedure will involve loading each of the CAFES submodels into the NADC 6600 and verification that all of the computing routines execute properly.

11.0 REFERENCES

1. Healy, M. J. Cockpit Geometry Evaluation, Phase 2-A, Vol. IV, D162-10128-2A, 1971, Boeing Aerospace Company.

2. Katz, R. Cockpit Geometry Evaluation, Phase 3, Vol. III, D162-10127-3, 1972, Boeing Aerospace Company.

3. Meister, D. Human Factors: Theory and Practice. New York: Wiley and Sons, 1971

4. Ryan, P. W. Cockpit Geometry Evaluation, Phase 3, Vol. I, D162-10125-3, 1972, Boeing Aerospace Company.

5. Ryan, P. W., Sather, H. N., and Bearse, A. W. Cockpit Geometry Evaluation, Phase 2-A, Vol. V, D162-10129-2A, 1971, Boeing Aerospace Company.

6. Parks, D. L. and Springer, W. E. Human Factors Engineering Analytic Process Definition and Criterion Development for CAFES, D180-18750-1, (in preparation), Boeing Aerospace Company.

7. Whitmore, D. C. CAFES Applications in Ship Systems Development, D180-18921-1, 1975, Boeing Aerospace Company.

8. Whitmore, D. C. and Parks, D. L. Computer Aided Function-Allocation Evaluation System, Phase 4, Vol. I, D180-18433-1, 1975, Boeing Aerospace Company.

APPENDIX A: MILSTAN FIXED WING ADDED TESTS ANALYSIS

Page No.*	Test No.	Coded Test Procedure
XII-63	1	Distance of LRUDPDCL/RRUPDPDCL left/right DEP
	2	Test distance of ALLPAN, ALLCP from (new) foot volume planes using AND connectors
XII-69	3	Distance of DEP above DEP2
	4	Distance of DEP from DEP2
	5	Distance of composite SEATPAN from (new) left limit plane for copilot seat
XII-92	6	Distance of composite INSTRPAN from (new) landing gear position indicator centroid LDGGPICP also distance of LDGGDN, LDGGUP from centroid
XII-93	7	Distance of composite CSGPAN from NSWHLSTG
XII-96	8	Distance of POWLEVCP from TURBRVTH
XII-99	9	Distance of FUELCR and/or FLSYSLCR from BSTPMP
	10	Distance of composite POWER from FUELCR
XII-105	11	Distance of composite POWER from (new) manual sight range point MANSIR
XII-107	12	Distance of composite RADIOCR forward of RAEBSTCT also Distance of RAEBSTCT from composite CONSOLE
	13	Distance of AFCCP from composite CONSOLE also Distance of composite POWER forward of AFCCP
XII-108	14	Distance of composite POWER aft of LDGGDN
	15	Distance of composite CONSOLE from LDFLPCR also Distance of composite POWER forward of LDFLPCR

*Page numbers refer to Appendix XII of Document D162-10127-3, Cockpit Geometry Evaluation Final Report (Phase III), Vol. III-Computer Program, Sept. 1972.

APPENDIX A: MILSTAN FIXED-WING ADDED TESTS ANALYSIS (cont.)

Page No.	Test No.	Coded Test Procedure
	16	Distance of composite CONSOLE from WGFLDCR
		also
		Distance of composite POWER forward of WGFLDCR
	17	Distance of composite POWER from EMGCYBR
	18	Distance of CANJETSC forward of DEP
		also
		Distance of (new) overhead panels composite from CANJETSC
		and
		Distance of composite EMPAN from CANJETSC
XII-110	19	Distance of DRGCHHN right of POWQUACP
		also
		Distance of DRGCHHN from POWQUACP
	20	Distance of DRGCHSW right of POWQUACP
		also
		Distance of DRGCHHN from POWQUACP
		also
		Distance of DRGCHSW aft of POWQUACP
	21	Distance of composite CONSOLE from POWQUACP
	22	Distance of TURBRVTH from POWQUACP
XII-111	23	Distance of composite CONSOLE from SUPCHGR
		also
		Distance of composite POWER forward of SUPCHGR
	24	Distance of (new) overhead panels composite from COOLCR
	25	Distance of composite CONSOLE from FLSYSLCR
		and
		Distance of composite POWER forward of FLSYSLCR
		also
		Distance of (new) overhead panels composite from FLSYSLCR
		and
		Distance of FLSYSLCR right of DEP
		and
		Distance of FLSYSLCR left of DEP2

APPENDIX A: MILSTAN FIXED-WING ADDED TESTS ANALYSIS (cont.)

Page No.	Test No.	Coded Test Procedure
XII-112	26	Distance of AIRSTSW from POWQUACP also Distance of AIRSTSW aft of POWQUACP also Distance of (new) overhead panels composite from AIRSTSW
	27	Distance of FEATHER forward of DEP also Distance of FEATHER above DEP
	28	Distance of composite CONSOLE from RAMAIRTB also Distance of composite POWER forward of RAMAIRTB
XII-114	29	Distance of composite POWER forward of VCOMMHF also Distance of composite CONSOLE from VCOMMHF
	30	Distance of composite CONSOLE from NAVCR also Distance of composite POWER forward of NAVCR
	31	Distance of composite CONSOLE from IFFSIF also Distance of NAVCR from IFFSIF
XII-115	32	Distance of OXYGEN forward of DEP also Distance of OXYGEN left of DEP Same tests for OXYGEN2 versus DEP2, except that distance right of DEP2 is tested.
	33	Distance of CMPQDSCN from OBSTPAN panel. Same test for CMPQDSC2 versus OBSTPAN2
	34	Distance of AGSUITCR from OBSTPAN panel. Same test for AGSUITC2 versus OBSTPAN2
	35	Distance of SHHARNLK from OBSTPAN panel and forward of DEP. Same tests for SHHARNL2 versus OBSTPAN2 and DEP2.

APPENDIX A: MILSTAN FIXED-WING ADDED TESTS ANALYSIS (cont.)

Page No.	Test No.	Coded Test Procedure
	36	Distance of SEATADJ from IBSTPAN panel and distance below NUTRLSRP. Same test for SEATADJ2 versus IBSTPAN2 and NUTRLSR2
XII-116	37	Distance of composite LCONSOLE from MAPSTOW. Same test for composite RCONSOLE versus MAPSTOW2
	38	Distance of OVHDPAN composite from AIPITHT
XII-175	39	Distance of VTSTADJ from IBSTPAN panel Distance of VTSTADJ2 from OBSTPAN2 panel
XII-189	40	Test not cost-effective using present program capability
	41	Same as 40
	42	Same as 40
	43	Angle of LPSTPAT with DEPZCP
	44	Distance of IBSTPAN and OBSTPAN from NUTRLSRP
	45	Included comment for this test stating the requirement
	46	Same as for 45
	47	Same as for 45
	48	Same as for 45
	49	Angle of CSBTP with DEPYCP
	50	Angle of CSCTP with DEPZCP
XII-227	51	Angle of RRUDPDL and LRUDPDL with DEPZCP. Note heel support requirement as a comment.

REQUIREMENTS	BOEMAN TEST YES	BOEMAN TEST NO	VECTOR GEOMETRY TEST YES	VECTOR GEOMETRY TEST NO	COMMENTS
1. The C_L of the rudder pedal shall be between ± 7.5" and ± 10.5" from the C_L of the crew station.		X	X		XII-63
2. A minimum clearance of 1.50" above and .75" on either side of the pedal shall be maintained over the maximum specified percentile foot in a flight boot.			X		XII-63 Flight boot specs. required
3. Both crewmembers shall be on same level unless otherwise specified.			X		XII-69 Test levels of NSRP at heel rest lines
4. Lateral spacing shall be a minimum of 26" and a maximum of 42" C_L to C_L for configurations with shared displays and controls.			X		XII-69
5. Absolute minimum clearance between seats shall be 3.00" for non-ejection seats and 6.00" for ejection seats.			X		XII-69

	CONTROL NAME	CONTROL LOCATION	BOEMAN TEST YES	BOEMAN TEST NO	VECTOR GEOMETRY TEST YES	VECTOR GEOMETRY TEST NO	COMMENTS
6.	Position Indicators	On instrument panel or adjacent to gear control visible to pilot from normal position.			L		XII-92
7.	Nose Wheel Steering	Pushbutton on control stick grip to engage and disengage.			L	A	XII-93
8.	Reverse Thrust Shaft Power	Integral with Power Lever			L	L,A	XII-96
9.	Boost Pumps	Adjacent to or integrated with fuel selector or integrated in diagrammatic fuel system.			L	A	XII-99
10.	Fuel Controls	Adjacent to Power Controls			L	A,C	XII-99 Fuel control selector switches shall be suitably designed so that a separate and distinct action is required to place switch in MANUAL position.

	CONTROL NAME	CONTROL LOCATION	BOEMAN TEST YES	BOEMAN TEST NO	VECTOR GEOMETRY TEST YES	VECTOR GEOMETRY TEST NO	COMMENTS
11.	Manual Sight Range	On power control			L	A	XII-105
12.	Rudder, Aileron and Elevator Booster Cutoff Control	Centrally located on center console aft of radio control. Accessible to both pilots.			L	A	XII-107
13.	Automatic Flight Controls	Center console aft of power controls and accessible to both pilots.			L,C	A	XII-107 If wheel controlled, disconnect switch shall be located on wheel opposite throttle hand. If wheel controlled and manual disconnect used, it shall be located in aft position of the controller. ?
14.	Landing Gear	Forward of power control when in full open position. Shall be operable by both pilots when in normal position.			L	A,C	XII-108 Same as Single

	CONTROL NAME	CONTROL LOCATION	BOEMAN TEST YES	BOEMAN TEST NO	VECTOR GEOMETRY TEST YES	VECTOR GEOMETRY TEST NO	COMMENTS
15.	Landing Flap Control	Center console aft of power controls	C		L	A	XII-108 Shall be possible for either pilot to operate control while maintaining normal forward visibility.
16.	Wing Folding Control	Center console aft of power control			L	A	XII-109
17.	Emergency Brake Control	Adjacent to power controls and operable by pilot			L	A	
18.	Canopy Jettison Control	Same as Single except secondary controls shall be located forward on overhead emergency panel			L	A	XII-109
19.	Drag Chute	Handle - on or adjacent to right side of power quadrant			L	A	XII-110

	CONTROL NAME	CONTROL LOCATION	BOEMAN TEST YES	BOEMAN TEST NO	VECTOR GEOMETRY TEST YES	VECTOR GEOMETRY TEST NO	COMMENTS
20.	Drag Chute	Switch - on adjacent or immediately aft of right side of power quadrant			L		XII-110
21.	Power Plant	On center console accessible to both pilots			L	A,C	XII-110 Additional power levers are authorized when required.
22.	Reverse Thrust Control (Turbojet)	On power quadrant and on same axis as power control			L	A,C	XII-110 With an engine failure in multiengine aircraft reverse thrust will be selectively applied only to operating engines of symmetry.
						C	Additional reverse thrust control is authorized when required.
23.	Supercharger	Center console and aft of power controls or outboard of and on same axis as the power controls				L,A	XII-111

	CONTROL NAME	CONTROL LOCATION	BOEMAN TEST YES	BOEMAN TEST NO	VECTOR GEOMETRY TEST YES	VECTOR GEOMETRY TEST NO	COMMENTS
24.	Cooling	Overhead panel			L	A	XII-111
25.	Fuel System Selector Controls	Grouped on center console aft of power controls or on overhead between pilots			L	A,C	XII-111 Same as single
26.	Air Start Switch	Aft or adjacent to power levers or on overhead panel			L	A	XII-112
27.	Propeller, Feathering	Forward and overhead, accessible to both pilots and in normal field of vision looking forward	L		L	A,C	XII-112
28.	Ram Air Turbine Class B & C Aircraft	Center console aft of power controls, operable by both pilots			L	A,C	XII-112 Design shall be distinctive from adjacent controls.

	CONTROL NAME	CONTROL LOCATION	BOEMAN TEST YES	BOEMAN TEST NO	VECTOR GEOMETRY TEST YES	VECTOR GEOMETRY TEST NO	COMMENTS
29.	Voice Comm. VH and UHF Controls	Aft of power controls on console accessible to both pilots					XII-114
30.	Nav. Controls	On center console aft of power quadrant					XII-114
31.	IFF/SIF	On center console adjacent to Nav. controls					XII-114
32.	Oxygen	Outboard and forward of each pilot	C		L		XII-115
33.	Composite Disconnect	Outboard side of each pilot's seat			L		XII-115
34.	Anti-G Suit Controls	Outboard of each pilot adjacent to seat			L	A	XII-115
35.	Shoulder Harness Lock	Forward on outboard side of each seat			L	A	XII-115

	CONTROL NAME	CONTROL LOCATION	BOEMAN TEST YES	BOEMAN TEST NO	VECTOR GEOMETRY TEST YES	VECTOR GEOMETRY TEST NO	COMMENTS
36.	Seat Adjustment	Inboard at base of each seat			A		XII-115
37.	Map Stowage	On left and right console			L	A	XII-116
38.	Anti-ice and Pilot Heat	On overhead readily accessible			L	A	XII-116

REQUIREMENTS	BOEMAN TEST YES	BOEMAN TEST NO	VECTOR GEOMETRY TEST YES	VECTOR GEOMETRY TEST NO	COMMENTS
39. <u>Adjustment control</u>. The vertical adjustment control shall be located on the right-hand side of the seat bucket and shall be easily accessible to the seat occupant. A momentary-ON, three-position center-OFF type switch shall be used. The switch shall be positioned so that the direction of switch actuation corresponds with the direction of seat movement.			X		XII-175 **Right side by VG--accessible by BOEMAN**
40. Lowest rear edge of seat to lowest point on the headrest and parallel to the CSBTL, shall be 32.3" maximum and 40.3" maximum to the top of the headrest.		X	X		XII-189
41. Heel rest line to bottom edge of the seat shall be: 5.125" and 0.063" for bombers and transports; and 3.125± 0.063" for fighters.		X	X		XII-189 **Requires input of the bottom of the seat.**

MIL-S-9479B (USAF)

	REQUIREMENTS	BOEMAN TEST YES	BOEMAN TEST NO	VECTOR GEOMETRY TEST YES	VECTOR GEOMETRY TEST NO	COMMENTS
42	The distance from the SRP to the inside *bottom of the seat structure* shall be 5.375" ± 0.063" and from the CSBTL to the inside seatback structure 5.0" ± 0.063".					XII-189
43	The lap strap attachment shall have an angle of $45^{o} \pm 2^{o}$ with the horizontal.		X	X		XII-189 Requires data input not needed by CGECPS
44	The maximum seat width (outside edges of seat sides) shall be 22" and the minimum width (inside edges of seat sides) shall be 18".		X	X		XII-189
	The headrest shall have:					
45	*Width 9.0" to 10.0"*		X	X		XII-189
46	Contact surface width of 1.50" ± .126:		X	X		From Figure 1 of MIL-S-9479B
47	Depth from forward edge to contact surface width of 2.0" ± .063"		X	X		
48	Contact surface 1.0" ± .063" behind the compressed seatback tangent line (CSBTL)		X	X		
49	CSBTL of $13^{o} \pm .5^{o}$		X	X		
50	Compressed seat cushion tangent line (CSCTL) of $6^{o} \pm .5^{o}$		X	X		

REQUIREMENTS	BOEMAN TEST YES	BOEMAN TEST NO	VECTOR GEOMETRY TEST YES	VECTOR GEOMETRY TEST NO	COMMENTS
51 Heel Support. When the pedal angle is greater than 20° above the horizontal, a heel support should be provided.		X	X		XII-227

APPENDIX B: MILSTAN - NEW STANDARD GEOMETRIC AND COMPOSITE OBJECTS

GEOMETRIC AND COMPOSITE OBJECTS

<u>Standard Input Points</u>

DEP2	design eye point (second pilot)
LDGGPICP	landing gear position indicator centroid
MANSIR	manual sight range
OXYGEN2	oxygen system (second pilot)
CMPQDSC2	composite quick disconnect (second pilot)
AGSUITC2	anti-G suit control (second pilot)
SHHARNL2	shoulder harness lock (second pilot)
SEATADJ2	seat adjustment (second pilot)
NUTRLSR2	neutral seat reference point (second pilot)
MAPSTOW2	map stowage (second pilot)
VSTADJ	vertical seat adjustment control
VSTADJ2	vertical seat adjustment control (second pilot)

Standard Input Planes

LFVPTP	left foot volume plane - top
LFVPBM	left foot volume plane - bottom
LFVPLS	left foot volume plane - left side
LFVPRS	left foot volume plane - right side
LFVPFR	left foot volume plane - front
LFVPRR	left foot volume plane - rear
RFVPTP	right foot volume plane - top
RFVPBM	right foot volume plane - bottom
RFVPLS	right foot volume plane - left side
RFVPRS	right foot volume plane - right side
RFVPFR	right foot volume plane - front
RFVPRR	right foot volume plane - rear
LLPSEAT2	left limit plane for seat (second pilot)
IBSTPAN	inboard seat panel
OBSTPAN	outboard seat panel
IBSTPAN2	inboard seat panel (second pilot)
OBSTPAN2	outboard seat panel (second pilot)
LPSTPAT	lap strap attachment
CSBTP	compressed seat back tangent plane
CSCTP	compressed seat cushion tangent plane

Standard Composites

OVHDPAN	overhead panels

APPENDIX C

EXISTING GEOMETRY-STANDARD OBJECTS USED IN THE NEWLY ADDED MILSTAN TESTS

Points - (37)

LRUDPDCL
RRUDPDCL
DEP
NSWHLSTG
POWLEVCP
TURBRVTH
BSTPMP
FUELCR
FLSYSLCR
RAEBSTCT
LDGGDN
LDGGUP
LDFLPCR
AFCCP
FEATHER
RAMAIRTB
VCOMMHF
NAVCR
IFFSIF
OXYGEN
CMPQDSCN
AGSUITCR
SHHARNLK
SEATADJ
MAPSTOW
AIPITHT
NUTRLSRP
WGFLDCR
EMGCYBR
CANJETSC
DRGCHHN
DRGCHSW
POWQUACP
TURBRVTH
SUPCHGR
COOLCR
AIRSTSW

Lines - (0)

Planes - (4)

DEPZCP
DEPYCP
RRUDPDL
LRUDPDL

Composites - (11)

SEATPAN
CSGPAN
POWER
RADIOCR
CONSOLE
THROTTLE
ALLPAN
ALLCP
LCONSOLE
RCONSOLE
EMPAN

```
            COMPUTER AIDED FUNCTION-ALLOCATION EVALUATION SYSTEM

BEGIN CAFES = CREATE NEW DATA BANK/
 BEGIN CAD/
  BEGIN EDITOR/
          DEFINE ELEMENT = CONTROL,POINT/
            REFERENCE POINT = 0,0/
            LENGTH = 0/
            SHAPE = 1,0,0.0,0.1/
       DEFINE SUBSYSTEM = S.1.0, PILOT STATION/
       DEFINE SUBSYSTEM = S.1.1, PILOT SEAT/
       DEFINE SUBSYSTEM = S.1.2, PILOT PANELS/
       DEFINE SUBSYSTEM = S.1.3, PILOT CONTROLS/
       DEFINE SUBSYSTEM = S.1.4, PILOT EYE REFERENCE POINT/
       DEFINE SUBSYSTEM = S.2.1, COCKPIT LINES/
       DEFINE SUBSYSTEM = S.3.1,PLANES WITH MANY BOUNDARY PTS/
         SUBSYSTEM = S.1.1/
          DEFINE ITEM = POINTS,SEAT BACK /
            POINTS =     7.50, 122.75, 274.97,
                         7.50,  99.15, 270.60,
                        -7.50,  99.15, 270.60,
                        -7.50, 122.75, 274.97/
     DEFINE ITEM = POINTS,SEAT PAN MID /
       POINTS = 7.5,99.15,264.85,-7.5,99.15,264.85,-7.5,100.45,257.82,7.5,
                100.45,257.82 /
         SUBSYSTEM = S.1.2/
         DEFINE ITEM = PANEL, UPPER LEFT MAIN INSTRU PANEL/
          PANEL COORD = -3.63, 116.35, 238.46,          -3.63, 120.56, 237.56,
                       -11.90, 116.35, 238.46 /
          3D BOUNDARY =  -3.63, 116.35, 238.46,       -11.90, 116.35, 238.46,
                         -9.58, 119.46, 238.01,        -6.98, 120.24, 237.53,
                         -4.52, 121.33, 237.40,        -3.63, 120.56, 237.56/
          ELEMENT = POINT,FI RAD ALT/PLACEMENT= 2.70, 1.90 /
          ELEMENT = POINT,SPEEDBRAKE/PLACEMENT= 1.76, 4.35 /
         DEFINE ITEM = PANEL, LOWER LEFT MAIN INSTRU PANEL/
          PANEL COORD = -3.24, 105.09, 240.85,         -3.24, 116.35, 238.46,
                      -14.75, 105.09, 240.85 /
          3D BOUNDARY =  -3.24, 105.09, 240.85,       -14.75, 105.09, 240.85,
                        -14.75, 112.55, 239.26,       -13.48, 114.69, 238.81,
                        -11.30, 116.35, 238.46,        -3.24, 116.35, 238.46/
          ELEMENT = POINT,FIACCELMTR/PLACEMENT = 5.00, 4.55/
          ELEMENT = POINT,FIAIRSPEED/PLACEMENT=  6.20, 1.65/
          ELEMENT = POINT,FIALTIMTR /PLACEMENT=  9.58, 1.65/
          ELEMENT = POINT,FIANGLATAK/PLACEMENT= 10.15, 4.55/
          ELEMENT = POINT,FIRSENGCTR/PLACEMENT=  4.55, 6.00/
          ELEMENT = POINT,FISTDBYADI/PLACEMENT=  3.30, 1.13/
          ELEMENT = POINT,FIVERTVEL /PLACEMENT=  7.50, 4.55/
          ELEMENT = POINT,FUEL QUANT/PLACEMENT=  2.08, 4.05/
          ELEMENT = POINT,MSTR FUNCT/PLACEMENT=  7.75, 7.75/
          ELEMENT= POINT,WSARMSTAT/PLACEMENT = 9.60, 8.50/
          ELEMENT= POINT,WSSALVJ   /PLACEMENT = 2.19,10.87/
          ELEMENT= POINT,WSSELJETT/PLACEMENT = 7.15,10.40/
     DEFINE ITEM = PANEL, CENTER MAIN INSTRU PANEL /
      PANEL COORD =  2.31, 105.09, 240.85,    2.31, 116.35, 238.46,
                    -3.24, 105.09, 240.85 /
      3D BOUNDARY =  2.31, 116.35, 238.46,    2.31, 105.09, 240.85,
                    -3.24, 105.09, 240.85,   -3.24, 116.35, 238.46 /
```


PRECEDING PAGE BLANK-NOT FILMED

```
      ELEMENT = POINT,ACAFWL      /PLACEMENT= 10.93, 2.62 /
      ELEMENT = POINT,ACALBL      /PLACEMENT= 10.93, 0.97 /
      ELEMENT = POINT,ACAMC       /PLACEMENT= 10.93, 4.42 /
      ELEMENT = POINT,EIADI       /PLACEMENT=  7.82, 2.62 /
      ELEMENT = POINT,EIADIET     /PLACEMENT=  5.73, 0.60 /
      ELEMENT = POINT,EIMST       /PLACEMENT=  2.52, 2.62 /
        SUBSYSTEM = S.1.3/
          DEFINE ITEM = POINT,AFTPTLT   /POINT = -26.00, 130.40,281.70/
          DEFINE ITEM = POINT,AFTPTREAR /POINT =   0.00,121.90,300.20/
          DEFINE ITEM = POINT,AFTPTRT   /POINT =  26.00,   0.00,281.70/
          DEFINE ITEM = POINT,NUTPLSRP  /POINT =   0.00, 99.15,270.60/
          DEFINE ITEM = POINT,SRP DOWN  /POINT =   0.00, 97.24,270.00/
          DEFINE ITEM = POINT,SRP UP    /POINT =   0.00,102.01,271.50/
        DEFINE ITEM = PLANE, TOP OF THROTTLE/
          PLANAR DEFINITION = -11.43, 106.76, 249.93,
                              -13.95, 106.76, 249.93,
                              -11.43, 107.06, 250.63/
        DEFINE  ITEM= POINT,ECTHRTLFWD/
          PLANE = TOP OF THROTTLE/
          2D POINT = 1.26, 0.01/
        SUBSYSTEM = S.1.4/
          DEFINE ITEM = RP, PILOT ERP/
            POINTS =    0.00, 130.40, 265.10,
                        5.00, 130.40, 265.10,
                        0.00, 130.40, 260.10/
        SUBSYSTEM = S.2.1/
        DEFINE ITEM = LINES,ZAXIS/
          POINTS = 0.00, 130.40, 265.10, 0.00, 131.40, 265.10/
        DEFINE ITEM = LINES,DEEMCLRY/
          POINTS = 0.00,  130.40, 265.10, -2.11, 115.782, 238.581/
        DEFINE ITEM = LINES,VRAYFWD/
          POINTS = 0.00, 130.40, 265.10, 0.00, 121.90, 230.0 /
        SUBSYSTEM = S.3.1/
        DEFINE ITEM = CIRCLE,TOP CENTER OF THROTTLE/
          PLANE = TOP OF THROTTLE/POINT = 1.26, 1.26/RADIUS = 1.26/
    DEFINE ITEM = POINTS,SEAT PAN LEFT FWD/
      POINTS = -2.25,100.45,257.82, -2.50,100.45,257.82, -2.75,100.45,257.82,
               -3.50,100.45,257.82, -4.50,100.45,257.82, -5.50,100.45,257.82,
               -6.50,100.45,257.82, -7.50,100.45,257.82, -7.50,101.27,253.39,
               -6.50,101.27,253.39, -5.50,101.27,253.39, -4.50,101.27,253.39,
               -3.50,101.27,253.39, -2.25,101.27,253.39 /
   END EDITOR/
   BEGIN REPORT GENERATOR/
    REPORT = DATA BANK SUMMARY/
     CATAGORY = ALL/
```

COORDINATE SYSTEM SUMMARY

DEWEY DECIMAL NUMBER	COORDINATE SYSTEM NAME
0.0	PRIMARY COORDINATE SYSTEM

```
COORDINATE SYSTEM: C.0
                    PRIMARY COORDINATE SYSTEM

     DEFINING POINTS:
                X                Y                Z
        --------------- --------------- ---------------
             .0               .0               .0
             1.0000000        .0               .0
             .0               1.0000000        .0

     SUBSYSTEMS:
          S.0                                PRIMARY SUBSYSTEM
           S.1.0                              PILOT STATION
           S.1.1                              PILOT SEAT
           S.1.2                              PILOT PANELS
           S.1.3                              PILOT CONTROLS
           S.1.4                              PILOT EYE REFERENCE POINT
           S.2.1                              COCKPIT LINES
           S.3.1                             PLANES WITH MANY BOUNDARY PTS

                        SUBSYSTEM SUMMARY
DEWEY DECIMAL NUMBER              SUBSYSTEM NAME
--------------------          --------------------
S.0                           PRIMARY SUBSYSTEM
 S.1.0                         PILOT STATION
 S.1.1                         PILOT SEAT
 S.1.2                         PILOT PANELS
 S.1.3                         PILOT CONTROLS
 S.1.4                         PILOT EYE REFERENCE POINT
 S.2.1                         COCKPIT LINES
 S.3.1                        PLANES WITH MANY BOUNDARY PTS

SUBSYSTEM: S.0
           PRIMARY SUBSYSTEM

     COORDINATE SYSTEM: C.0
                        PRIMARY COORDINATE SYSTEM

     GEOMETRIC ITEMS AND PANELS:

SUBSYSTEM:  S.1.0
            PILOT STATION

     COORDINATE SYSTEM: C.0
                        PRIMARY COORDINATE SYSTEM

     GEOMETRIC ITEMS AND PANELS:

SUBSYSTEM:  S.1.1
            PILOT SEAT

     COORDINATE SYSTEM: C.0
                        PRIMARY COORDINATE SYSTEM

     GEOMETRIC ITEMS AND PANELS:
                       SEAT BACK
                       SEAT PAN MID
```

SUBSYSTEM: S.1.2
PILOT PANELS

COORDINATE SYSTEM: C.0
PRIMARY COORDINATE SYSTEM

GEOMETRIC ITEMS AND PANELS:
UPPER LEFT MAIN INSTRU PANEL
LOWER LEFT MAIN INSTRU PANEL
CENTER MAIN INSTRU PANEL

SUBSYSTEM: S.1.3
PILOT CONTROLS

COORDINATE SYSTEM: C.0
PRIMARY COORDINATE SYSTEM

GEOMETRIC ITEMS AND PANELS:
AFTPTLT
AFTPTREAR
AFTPTRT
NUTRLSRP
SRP DOWN
SRP UP
TOP OF THROTTLE
FCTHRTLFWD

SUBSYSTEM: S.1.4
PILOT EYE REFERENCE POINT

COORDINATE SYSTEM: C.0
PRIMARY COORDINATE SYSTEM

GEOMETRIC ITEMS AND PANELS:
PILOT ERP

SUBSYSTEM: S.2.1
COCKPIT LINES

COORDINATE SYSTEM: C.0
PRIMARY COORDINATE SYSTEM

GEOMETRIC ITEMS AND PANELS:
ZAXIS
DEFNCLRY
VRAYFWD

SUBSYSTEM: S.2.1
PLANES WITH MANY BOUNDARY PTS

COORDINATE SYSTEM: C.0
PRIMARY COORDINATE SYSTEM

GEOMETRIC ITEMS AND PANELS:
TOP CENTER OF THROTTLE
SEAT PAN LEFT FWD

GEOMETRIC ITEM SUMMARY

ITEM NAMES

SEAT BACK
SEAT PAN MID
AFTPTLT
AFTFTREAR
AFTPTRT
NUTRLSRP
SRP DOWN
SRP UP
TOP OF THROTTLE
FCTHRTLFWD
PILOT ERP
ZAXIS
DEFMCLRY
VRAYFWD
TOP CENTER OF THROTTLE
SEAT PAN LEFT FWD

GEOMETRIC ITEM: SEAT BACK
POINTS

SUBSYSTEM: S.1.1

POINTS:

X	Y	Z
7.500000	122.7500	274.9700
7.500000	99.15000	270.6000
-7.500000	99.15000	270.6000
-7.500000	122.7500	274.9700

GEOMETRIC ITEM: SEAT PAN MID
POINTS

SUBSYSTEM: S.1.1

POINTS:

X	Y	Z
7.500000	99.15000	264.8500
-7.500000	99.15000	264.8500
-7.500000	100.4500	257.8200
7.500000	100.4500	257.8200

GEOMETRIC ITEM: AFTPTLT
POINTS

SUBSYSTEM: S.1.3

POINTS:

X	Y	Z
-26.00000	130.4000	281.7000

GEOMETRIC ITEM: AFTPTREAR POINTS

SUBSYSTEM: S.1.3

POINTS:

X	Y	Z
.0	121.9000	300.2000

GEOMETRIC ITEM: AFTPTPT POINTS

SUBSYSTEM: S.1.3

POINTS:

X	Y	Z
26.00000	.0	281.7000

GEOMETRIC ITEM: NUTPLSRP POINTS

SUBSYSTEM: S.1.3

POINTS:

X	Y	Z
.0	99.15000	270.6000

GEOMETRIC ITEM: SRP DOWN POINTS

SUBSYSTEM: S.1.3

POINTS:

X	Y	Z
.0	97.24000	270.0000

GEOMETRIC ITEM: SRP UP POINTS

SUBSYSTEM: S.1.3

POINTS:

X	Y	Z
.0	102.0100	271.5000

GEOMETRIC ITEM: TOP OF THROTTLE PLANE

SUBSYSTEM: S.1.3

COORDINATE DEFINITION:

POINTS:

X	Y	Z
-11.43000	106.7600	249.9300
-12.95000	106.7600	249.9300
-11.43000	107.0600	250.6300

GEOMETRIC ITEM: ECTHRTLEWD
POINTS

SUBSYSTEM: S.1.3

POINTS:

X	Y	Z
-12.69000	106.7639	249.9392

GEOMETRIC ITEM: PILOT ERP
REF. POINT

SUBSYSTEM: S.1.4

COORDINATE DEFINITION:
POINTS:

X	Y	Z
.0	130.4000	265.1000
5.000000	130.4000	265.1000
.0	130.4000	260.1000

GEOMETRIC ITEM: ZAXIS
LINES

SUBSYSTEM: S.2.1

POINTS:

X	Y	Z
.0	130.4000	265.1000
.0	131.4000	265.1000

GEOMETRIC ITEM: DEFMCLRY
LINES

SUBSYSTEM: S.2.1

POINTS:

X	Y	Z
.0	130.4000	265.1000
-2.110000	115.7820	238.5810

GEOMETRIC ITEM: VRAYEWD
LINES

SUBSYSTEM: S.2.1

POINTS:

X	Y	Z
.0	130.4000	265.1000
.0	121.9000	230.0000

GEOMETRIC ITEM: TOP CENTER OF THROTTLE
CIRCLE

SUBSYSTEM: 5.3.1

POINTS:

X	Y	Z
-12.69000	107.7527	252.2462
-12.85794	107.7482	252.2359
-13.02289	107.7350	252.2051
-13.18189	107.7133	252.1543
-13.33212	107.6834	252.0846
-13.47088	107.6459	251.9970
-13.59572	107.6014	251.8932
-13.70439	107.5508	251.7751
-13.79496	107.4949	251.6447
-13.86581	107.4347	251.5044
-13.91568	107.3714	251.3566
-13.94367	107.3060	251.2040
-13.94930	107.2398	251.0494
-13.93245	107.1738	250.8955
-13.89343	107.1093	250.7450
-13.83293	107.0474	250.6006
-13.75204	106.9893	250.4650
-13.65220	106.9359	250.3404
-13.53519	106.8882	250.2292
-13.40309	106.8471	250.1333
-13.25827	106.8133	250.0545
-13.10331	106.7875	249.9941
-12.94097	106.7699	249.9532
-12.77416	106.7611	249.9326
-12.60584	106.7611	249.9326
-12.43903	106.7699	249.9532
-12.27669	106.7875	249.9941
-12.12173	106.8133	250.0545
-11.97691	106.8471	250.1333
-11.84481	106.8882	250.2292
-11.72780	106.9359	250.3404
-11.62796	106.9893	250.4650
-11.54707	107.0474	250.6006
-11.48657	107.1093	250.7450
-11.44755	107.1738	250.8955
-11.43070	107.2398	251.0494
-11.43633	107.3060	251.2040
-11.46432	107.3714	251.3566
-11.51419	107.4347	251.5044
-11.58504	107.4949	251.6447
-11.67561	107.5508	251.7751
-11.78428	107.6014	251.8932
-11.90912	107.6459	251.9970
-12.04788	107.6834	252.0846
-12.19811	107.7133	252.1543
-12.35711	107.7350	252.2051
-12.52206	107.7482	252.2359
-12.69000	107.7527	252.2462

```
GEOMETRIC ITEM: SEAT PAN LEFT FWD
                POINTS

      SUBSYSTEM:  5.3.1

        POINTS:
              X                   Y                   Z
        -------------- -------------- --------------
            -2.250000        100.4500          257.8200
            -2.500000        100.4500          257.8200
            -2.750000        100.4500          257.8200
            -3.500000        100.4500          257.8200
            -4.500000        100.4500          257.8200
            -5.500000        100.4500          257.8200
            -6.500000        100.4500          257.8200
            -7.500000        100.4500          257.8200
            -7.500000        101.2700          253.3900
            -6.500000        101.2700          253.3900
            -5.500000        101.2700          253.3900
            -4.500000        101.2700          253.3900
            -3.500000        101.2700          253.3900
            -2.250000        101.2700          253.3900

INSTRUMENT/CONTROL PANEL SUMMARY

    PANEL NAMES
--------------------
 UPPER LEFT MAIN INSTRU PANEL
 LOWER LEFT MAIN INSTRU PANEL
 CENTER MAIN INSTRU PANEL

PANEL:  UPPER LEFT MAIN INSTRU PANEL
  SUBSYSTEM:  5.1.2

    PANEL COORDINATES(X,Y,Z):
            -3.630000        116.3500          238.4600
            -3.630000        120.5600          237.5600
            -11.90000        116.3500          238.4600
    BOUNDARY(X,Y):
             .0              .0
             .0              8.270000
             2.157452        5.950000
             3.098467        3.350000
             5.091560        .8900000
             4.305125        .0

    ELEMENT: POINT
        LOCATION POINT(X,Y):     2.760000          1.900000
        THETA,PHI,HEIGHT:     .0                .0               .0
        ELEMENT LABEL: FI RAD ALT

    ELEMENT: POINT
        LOCATION POINT(X,Y):     1.760000          4.350000
        THETA,PHI,HEIGHT:     .0                .0               .0
        ELEMENT LABEL: SPEEDBRAKE
```

```
PANEL: LOWER LEFT MAIN INSTRU PANEL
  SUBSYSTEM: 5.1.2

  PANEL COORDINATES(X,Y,Z):
          -3.240000       105.0900        240.8500
          -3.240000       116.3500        238.4600
          -14.75000       105.0900        240.8500
  BOUNDARY(X,Y):
          .0              .0
          .0              11.51000
          7.627559        11.51000
          9.914357        10.24000
          11.51085        8.660000
          11.51085        .0

  ELEMENT: POINT
      LOCATION POINT(X,Y):    5.000000        4.550000
      THETA,PHI,HEIGHT:   .0          .0          .0
      ELEMENT LABEL: FIACCELMTR

  ELEMENT: POINT
      LOCATION POINT(X,Y):    6.200000        1.650000
      THETA,PHI,HEIGHT:   .0          .0          .0
      ELEMENT LABEL: FIAIRSPEED

  ELEMENT: POINT
      LOCATION POINT(X,Y):    9.560000        1.650000
      THETA,PHI,HEIGHT:   .0          .0          .0
      ELEMENT LABEL: FIALTIMTR

  ELEMENT: POINT
      LOCATION POINT(X,Y):    10.15000        4.550000
      THETA,PHI,HEIGHT:   .0          .0          .0
      ELEMENT LABEL: FIANGLATAK

  ELEMENT: POINT
      LOCATION POINT(X,Y):    4.550000        8.000000
      THETA,PHI,HEIGHT:   .0          .0          .0
      ELEMENT LABEL: FIRSENGCTR

  ELEMENT: POINT
      LOCATION POINT(X,Y):    3.200000        1.130000
      THETA,PHI,HEIGHT:   .0          .0          .0
      ELEMENT LABEL: FISTBSYADI

  ELEMENT: POINT
      LOCATION POINT(X,Y):    7.500000        4.550000
      THETA,PHI,HEIGHT:   .0          .0          .0
      ELEMENT LABEL: FIVERTVEL

  ELEMENT: POINT
      LOCATION POINT(X,Y):    2.080000        4.050000
      THETA,PHI,HEIGHT:   .0          .0          .0
      ELEMENT LABEL: FUEL QUANT

  ELEMENT: POINT
      LOCATION POINT(X,Y):    7.750000        7.750000
      THETA,PHI,HEIGHT:   .0          .0          .0
      ELEMENT LABEL: MSTR FUNCT
```

```
ELEMENT: POINT
     LOCATION POINT(X,Y):     9.600000          8.500000
     THETA,PHI,HEIGHT:      .0               .0               .0
     ELEMENT LABEL: WSARMSTAT

ELEMENT: POINT
     LOCATION POINT(X,Y):     2.190000          10.87000
     THETA,PHI,HEIGHT:      .0               .0               .0
     ELEMENT LABEL: WSSALVJ

ELEMENT: POINT
     LOCATION POINT(X,Y):     7.150000          10.40000
     THETA,PHI,HEIGHT:      .0               .0               .0
     ELEMENT LABEL: WSSELJETT

PANEL:  UPPER LEFT MAIN INSTRU PANEL
   SUBSYSTEM:  5.1.2

 PANEL COORDINATES(X,Y,Z):
          -3.630000        116.3500        238.4600
          -3.630000        120.5600        237.5600
          -11.90000        116.3500        239.4600
 BOUNDARY(X,Y):
          .0               .0
          .0               8.270000
          2.157452         5.950000
          3.098467         3.350000
          5.091560         .9900000
          4.305125         .0

ELEMENT: POINT
     LOCATION POINT(X,Y):     2.700000          1.900000
     THETA,PHI,HEIGHT:      .0               .0               .0
     ELEMENT LABEL: FI RAD ALT

ELEMENT: POINT
     LOCATION POINT(X,Y):     1.760000          4.350000
     THETA,PHI,HEIGHT:      .0               .0               .0
     ELEMENT LABEL: SPEEDBRAKE

PANEL:  CENTER MAIN INSTRU PANEL
   SUBSYSTEM:  5.1.2

 PANEL COORDINATES(X,Y,Z):
          2.310000         105.0900        240.8500
          2.310000         116.3500        238.4600
          -3.240000        105.0900        240.8500
 BOUNDARY(X,Y):
          11.51085         .0
          .0               .0
          .0               5.550000
          11.51085         5.550000

ELEMENT: POINT
     LOCATION POINT(X,Y):     10.93000          2.620000
     THETA,PHI,HEIGHT:      .0               .0               .0
     ELEMENT LABEL: ACAEWL

ELEMENT: POINT
     LOCATION POINT(X,Y):     10.93000          .9700000
     THETA,PHI,HEIGHT:      .0               .0               .0
     ELEMENT LABEL: ACALBL
```

```
ELEMENT: POINT
     LOCATION POINT(X,Y):     10.93000          4.420000
     THETA,PHI,HEIGHT:     .0                   .0                 .0
     ELEMENT LABEL: ACAMC

ELEMENT: POINT
     LOCATION POINT(X,Y):     7.820000          2.620000
     THETA,PHI,HEIGHT:     .0                   .0                 .0
     ELEMENT LABEL: FIAPT

ELEMENT: POINT
     LOCATION POINT(X,Y):     5.730000          .8000000
     THETA,PHI,HEIGHT:     .0                   .0                 .0
     ELEMENT LABEL: FIAPIST

ELEMENT: POINT
     LOCATION POINT(X,Y):     2.520000          2.620000
     THETA,PHI,HEIGHT:     .0                   .0                 .0
     ELEMENT LABEL: FIMSI

INSTRUMENT/CONTROL GROUP SUMMARY

     GROUP NAMES
   --------------------

     NONE

  CATALOGED ELEMENT SUMMARY

   ELEMENT NAMES
  --------------------
 POINT


 ELEMENT: POINT
    TYPE: CONTROL
    REFERENCE POINT(X,Y):     .0                .0
    LENGTH:     .0
    SHAPE TYPE: CIRCULAR
    SHAPE DESCRIPTION(X,Y):
         .0            .0
       RADIUS:     .1000000
    HEIGHT ABOVE PANEL:     .0
   END REPORT GENERATOR/


END CAD/
  BEGIN CGF INTERFACE/
   PUNCH = CAD DATA/
    STORAGE = LIST/
    ERR = PILOT ERR/
  COCKPIT DESCRIPTION = A7E,A7E COCKPIT PILOTS STATION/
    SUBSYSTEM = S.1.2/
    SUBSYSTEM = S.1.1, S.1.3 /
   PUNCH = CAD DATA/
PUNCHING OF STORAGE DATA COMPLETED.   60 CARDS WERE PUNCHED.
```

LISTING OF PUNCHED DECK

```
TABLE NAME = COCKPITA7E
THIS DATA SET CONTAINS A SET OF VERTICIES CORRESPONDING TO EACH COCKPIT
PLANE IN THE A7E COCKPIT PILOTS STATION
 5
 UPPER LEFT MAIN INSTRU PANEL              1 6
  -3.630  26.640 -14.050 -11.900  26.640 -14.050  -9.580  27.091 -11.940
  -6.980  27.476 -10.140  -4.520  27.704  -9.071  -3.630  27.540  -9.840
 LOWER LEFT MAIN INSTRU PANEL              2 6
  -3.240  24.250 -25.310 -14.750  24.250 -25.310 -14.750  25.834 -17.849
 -13.490  26.288 -15.710 -11.900  26.640 -14.050  -3.240  26.640 -14.050
 CENTER MAIN INSTRU PANEL                  3 4
   2.310  26.640 -14.050   2.310  24.250 -25.310  -3.240  24.250 -25.310
  -3.240  26.640 -14.050
SEAT BACK                                  4 4
   7.500  -9.870  -7.650   7.500  -5.500 -31.250  -7.500  -5.500 -31.250
  -7.500  -9.870  -7.650
SEAT PAN MID                               5 4
   7.500    .250 -31.250  -7.500    .250 -31.250  -7.500   7.280 -29.950
   7.500   7.280 -29.950
TABLE NAME =
TABLE NAME = CONTROLA7E
THIS SET OF DATA CONSISTS OF A COCKPIT CONTROL CODE DICTIONARY, WITH CONTROL
CODE NAMES AND CONTROL CODE COORDINATES IN THE ERP COORDINATE SYSTEM
FOR THE A7E COCKPIT PILOTS STATION
 27
FIRADALT       -5.530     27.204    -11.410     1
SPEEDBRAKE     -7.980     27.008    -12.329     1
FIACCELMTR     -7.790     25.288    -20.419     2
FIAIRSPEED     -4.890     25.537    -19.245     2
FIALTIMTR      -4.890     26.239    -15.939     2
FIANGLATAK     -7.790     26.357    -15.381     2
FIRSENGCTR    -11.240     25.195    -20.859     2
FISTBYADI      -4.370     24.925    -22.082     2
FIVERTVEL      -7.790     25.807    -17.973     2
FUELQUANT      -7.290     24.682    -23.275     2
MSTRFUNCT     -10.990     25.859    -17.729     2
WSARMSTAT     -11.740     26.243    -15.919     2
WSSALVJ       -14.110     24.705    -23.168     2
WSSELJETT     -13.640     25.735    -18.316     2
ACAFVL          -.310     26.519    -14.618     3
ACALPL          1.340     26.519    -14.618     3
ACAMC          -2.110     26.519    -14.618     3
FIADI           -.310     25.874    -17.660     3
FIADIET         1.510     25.440    -19.705     3
FIMST           -.310     24.773    -22.845     3
AFTRTLT       -26.000    -16.600       .000    -0
AFTRTREAR        .000    -35.100     -6.500    -0
AFTRTRT        26.000    -16.600   -130.400    -0
NUTRLSRP         .000     -5.500    -31.250    -0
SRPDOWN          .000     -4.900    -33.160    -0
SRPUP            .000     -6.400    -28.390    -0
FCTHRTLFWD    -12.690     15.161    -23.636    -0
TABLE NAME =
TABLE NAME = CONSHAPA7E
THIS DATA SET DEFINES THE NAMES OF CONTROL SHAPES AND COCKPIT OBJECTS AND
```

```
THEIR CORRESPONDING PLANE DESIGNATION NUMBERS USING LOWER AND UPPER BOUNDS
   ?
  PILOT PANELS                           1    3
  PILOT SEAT                             4    5
 TABLE NAME =

     COMP = LIST/
     EPP = PILOT EPP/
   COCKPIT DESCRIPTION = A7E,A7E COCKPIT PILOTS STATION/
       PLANE NAMES = SPTP,SPANMID,SPANEWDL/
       PLANE NAMES = ULMIPAN,LLMIPAN,CMIPAN/
       PLANE NAME = THRTLTPC/
     SUBSYSTEM = S.1.1,S.1.2,S.1.3/
       SUBSYSTEM = S.2.1/
    PUNCH = CAD DATA/
 PUNCHING OF COMP DATA COMPLETED.   52 CARDS WERE PUNCHED.


            LISTING OF PUNCHED DECK
            -----------------------

  DATA
  POINTS
  FIPADALT     -5.530     27.204    -11.410
  SPEEDBRA     -7.990     27.008    -12.329
  FIACCELM     -7.790     25.288    -20.419
  FIAIRSPE     -4.890     25.537    -19.245
  FIALTIMT     -4.890     26.239    -15.939
  FIANGLAT     -7.790     26.357    -15.381
  FIRSENGC    -11.240     25.195    -20.859
  FISTDBYA     -4.370     24.935    -22.082
  FIVERTVE     -7.790     25.807    -17.973
  FUELQUAN     -7.290     24.682    -23.275
  MSTREUNC    -10.990     25.859    -17.729
  WSARMSTA    -11.740     26.243    -15.919
  WSSALVJ     -14.110     24.705    -23.168
  WSSELJET    -13.640     25.735    -18.316
  ACAFWL        -.310     26.519    -14.618
  ACALRL        1.340     26.519    -14.618
  ACAMC        -2.110     26.519    -14.618
  FIADI         -.310     25.874    -17.660
  FIADIET       1.510     25.440    -19.705
  FIMST         -.310     24.773    -22.845
  AFTRTLT     -26.000    -16.600       .000
  AFTRTREA       .000    -35.100     -8.500
  AFTRTRT      26.000    -16.600   -130.400
  NUTRLSPR       .000     -5.500    -31.250
  SPPDOWN        .000     -4.900    -33.160
  SPPUP          .000     -6.400    -28.390
  FCTHRTLE    -12.690     15.161    -23.636
  *
  LINES
  ZAXIS          .000       .000       .000       .000      .000     1.000
  DEFMCLPY       .000       .000       .000     -2.110    26.519   -14.619
  VRAYEWP        .000       .000       .000       .000    35.100    -8.500
  *
```

```
PLANES
SEAT BACK                           SBTP        4
   7.500  -9.870  -7.650   7.500  -5.500 -31.250  -7.500  -5.500 -31.250
  -7.500  -9.870  -7.650
SEAT PAN MID                        SPANMID     4
   7.500    .250 -31.250  -7.500    .250 -31.250  -7.500   7.280 -29.950
   7.500   7.280 -29.950
 UPPER LEFT MAIN INSTRU PANEL SPANFWDL          6
  -3.630  26.640 -14.050 -11.900  26.640 -14.050  -9.580  27.091 -11.940
  -6.980  27.476 -10.140  -4.520  27.704  -9.071  -3.630  27.540  -9.840
 LOWER LEFT MAIN INSTRU PANEL ULMIPAN           6
  -3.240  24.250 -25.310 -14.750  24.250 -25.310 -14.750  25.834 -17.849
 -13.480  26.288 -15.710 -11.900  26.640 -14.050  -3.240  26.640 -14.050
 CENTER MAIN INSTRU PANEL           LLMIPAN     4
   2.310  26.640 -14.050   2.310  24.250 -25.310  -3.240  24.250 -25.310
  -3.240  26.640 -14.050
*


      STORAGE = LIST/
      FRP = PILOT FRP/
      COCKPIT DESCRIPTION = AZE,AZE PILOT STATION WITH 2 SUBDIVIDED PLANES/
       SUBSYSTEM = S.1.2,S.1.1,S.1.3,S.3.1/


 THE FOLLOWING PLANE CONTAINED MORE THAN SIX BOUNDARY
 POINTS AND WAS SUBDIVIDED INTO 12 PLANES
      TOP CENTER OF THROTTLE


 THE FOLLOWING PLANE CONTAINED MORE THAN SIX BOUNDARY
 POINTS AND WAS SUBDIVIDED INTO  3 PLANES
      SEAT PAN LEFT FWD


     END CGE INTERFACE/
 PUNCHING OF STORAGE DATA COMPLETED.  106 CARDS WERE PUNCHED.
```

LISTING OF PUNCHED DECK

```
TABLE NAME = COCKPITA7E
THIS DATA SET CONTAINS A SET OF VERTICIES CORRESPONDING TO EACH COCKPIT
PLANE IN THE A7E PILOT STATION WITH 2 SUBDIVIDED PLANES
 20
 UPPER LEFT MAIN INSTRU PANEL                    1 6
   -3.620  26.640 -14.050 -11.900  26.640 -14.050  -9.580  27.091 -11.940
   -6.980  27.476 -10.140  -4.520  27.704  -9.071  -3.630  27.540  -9.840
 LOWER LEFT MAIN INSTRU PANEL                    2 6
   -3.240  24.250 -25.310 -14.750  24.250 -25.310 -14.750  25.834 -17.849
  -13.490  26.288 -15.710 -11.900  26.640 -14.050  -3.240  26.640 -14.050
 CENTER MAIN INSTRU PANEL                        3 4
    2.310  26.640 -14.050   2.310  24.250 -25.310  -3.240  24.250 -25.310
   -3.240  26.640 -14.050
SEAT BACK                                        4 4
    7.500  -9.870  -7.650   7.500  -5.500 -31.250  -7.500  -5.500 -31.250
   -7.500  -9.870  -7.650
SEAT PAN MID                                     5 4
    7.500    .250 -31.250  -7.500    .250 -31.250  -7.500   7.280 -29.950
    7.500   7.280 -29.950
TOP CENTER OF THROTTLE                           6 6
  -12.690  12.854 -22.647 -12.858  12.864 -22.652 -13.023  12.895 -22.665
  -13.182  12.946 -22.687 -13.332  13.015 -22.717 -13.471  13.103 -22.754
TOP CENTER OF THROTTLE                           7 6
  -12.690  12.854 -22.647 -13.471  13.103 -22.754 -13.596  13.207 -22.799
  -13.704  13.325 -22.849 -13.795  13.455 -22.905 -13.866  13.596 -22.965
TOP CENTER OF THROTTLE                           8 6
  -12.690  12.854 -22.647 -13.866  13.596 -22.965 -13.916  13.743 -23.029
  -13.944  13.896 -23.094 -13.949  14.051 -23.160 -13.932  14.205 -23.226
TOP CENTER OF THROTTLE                           9 6
  -12.690  12.854 -22.647 -13.932  14.205 -23.226 -13.893  14.355 -23.291
  -13.833  14.499 -23.353 -13.752  14.635 -23.411 -13.652  14.760 -23.464
TOP CENTER OF THROTTLE                          10 6
  -12.690  12.854 -22.647 -13.652  14.760 -23.464 -13.535  14.871 -23.512
  -13.403  14.967 -23.553 -13.258  15.046 -23.587 -13.103  15.106 -23.613
TOP CENTER OF THROTTLE                          11 6
  -12.690  12.854 -22.647 -13.103  15.106 -23.613 -12.941  15.147 -23.630
  -12.774  15.167 -23.639 -12.606  15.167 -23.639 -12.439  15.147 -23.630
TOP CENTER OF THROTTLE                          12 6
  -12.690  12.854 -22.647 -12.439  15.147 -23.630 -12.277  15.106 -23.613
  -12.122  15.046 -23.587 -11.977  14.967 -23.553 -11.845  14.871 -23.512
TOP CENTER OF THROTTLE                          13 6
  -12.690  12.854 -22.647 -11.845  14.871 -23.512 -11.728  14.760 -23.464
  -11.628  14.635 -23.411 -11.547  14.499 -23.353 -11.487  14.355 -23.291
TOP CENTER OF THROTTLE                          14 6
  -12.690  12.854 -22.647 -11.487  14.355 -23.291 -11.448  14.205 -23.226
  -11.431  14.051 -23.160 -11.436  13.896 -23.094 -11.464  13.743 -23.029
TOP CENTER OF THROTTLE                          15 6
  -12.690  12.854 -22.647 -11.464  13.743 -23.029 -11.514  13.596 -22.965
  -11.585  13.455 -22.905 -11.676  13.325 -22.849 -11.784  13.207 -22.799
TOP CENTER OF THROTTLE                          16 6
  -12.690  12.854 -22.647 -11.784  13.207 -22.799 -11.909  13.103 -22.754
  -12.049  13.015 -22.717 -12.198  12.946 -22.687 -12.357  12.895 -22.665
TOP CENTER OF THROTTLE                          17 4
  -12.690  12.854 -22.647 -12.357  12.895 -22.665 -12.522  12.864 -22.652
  -12.690  12.854 -22.647
```

```
SEAT PAN LEFT FWD                                 18 6
  -2.250    7.280 -29.950   -2.500     7.280 -29.950   -2.750     7.280 -29.950
  -3.500    7.280 -29.950   -4.500     7.280 -29.950   -5.500     7.280 -29.950
SEAT PAN LEFT FWD                                 19 6
  -2.250    7.280 -29.950   -5.500     7.280 -29.950   -6.500     7.280 -29.950
  -7.500    7.280 -29.950   -7.500    11.710 -29.130   -6.500    11.710 -29.130
SEAT PAN LEFT FWD                                 20 6
  -2.250    7.280 -29.950   -6.500    11.710 -29.130   -5.500    11.710 -29.130
  -4.500   11.710 -29.130   -3.500    11.710 -29.130   -2.250    11.710 -29.130
TABLE NAME =
TABLE NAME = CONTROLA7E
THIS SET OF DATA CONSISTS OF A COCKPIT CONTROL CODE DICTIONARY, WITH CONTROL
CODE NAMES AND CONTROL CODE COORDINATES IN THE ERP COORDINATE SYSTEM
FOR THE A7E PILOT STATION WITH 2 SUBDIVIDED PLANES
 27
FIRADALT        -5.530      27.204     -11.410      1
SPEEDBRAKE      -7.990      27.008     -12.329      1
FIACCELMTR      -7.700      25.268     -20.419      2
FIAIRSPEED      -4.990      25.537     -19.245      2
FIALTIMTR       -4.890      26.239     -15.939      2
FIANGLATAK      -7.730      26.357     -15.381      2
FIRSENGCTR     -11.240      25.195     -20.859      2
FISTBYADI       -4.270      24.935     -22.082      2
FIVERTVEL       -7.790      25.807     -17.973      2
FUELQUANT       -7.290      24.682     -23.275      2
MSTRCUNCT      -10.990      25.859     -17.729      2
WSARMSTAT      -11.740      26.243     -15.919      2
WSSALVJ        -14.110      24.705     -23.168      2
WSSELJETT      -13.640      25.735     -18.316      2
ACAFWL           -.310      26.519     -14.618      3
ACALPL           1.340      26.519     -14.618      3
ACAMC           -2.110      26.519     -14.618      3
FIADI            -.310      25.874     -17.660      3
FIADIET          1.510      25.440     -19.705      3
FIMST            -.310      24.773     -22.845      3
AFTRTLT        -26.000     -16.600        .000     -0
AFTRTREAR         .000     -35.100      -8.500     -0
AFTRTRT         26.000     -16.600    -130.400     -0
NUTRLSPR          .000      -5.500     -31.250     -0
SRPDOWN           .000      -4.900     -33.160     -0
SRPUP             .000      -6.400     -28.390     -0
FCTHRTLFWD     -12.690      15.261     -23.636     -0
TABLE NAME =
TABLE NAME = CONSHAPA7E
THIS DATA SET DEFINES THE NAMES OF CONTROL SHAPES AND COCKPIT OBJECTS AND
THEIR CORRESPONDING PLANE DESIGNATION NUMBERS USING LOWER AND UPPER BOUNDS
    3
 PILOT PANELS                          1    3
 PILOT SEAT                            4    5
PLANES WITH MANY BOUNDARY PTS          6   20
TABLE NAME =

 END CAFES/
```

APPENDIX E: INPUT VARIABLES FOR CGE REACH BASKET MODEL

CARD	INPUT VARIABLE	FORMAT	DESCRIPTION
1	(TITLE(I),I=1,8)	8A10	80-character title
2	NCALL,ISKIP,IP,IPØSE, NSTEPS,LI,LM	20I4	Use the values 2, 1, 0, 1, 100, blank, blank. If optimization output is to be desired, use IP=9 (partial) or IP=4 (full). LI and LM have defaults.
3	ICØNST, NMJ, NMJUT	20I4	ICØNST = 2*LE (see below). NMJ = total number of moveable links used. NMJUT = NMJ for upper body reach analysis.
4	IA,IB,IC,ID,IE,IJØIN, IUB,NUB,MUB	20I4	IUB = number of links (including rigid links) in spine/right arm and also in spine/left arm systems. NUB = number of links in spine and head. MUB = number of links in each leg. IA = ISPRA(IUB) (see below) IB = ILA(IUB) IC = IH(NUB) ID = IRL(MUB) IE = ILL(MUB) IJØIN = ISPRA index of the last spine link (usually = 2).

CARD	INPUT VARIABLE	FORMAT	DESCRIPTION
5	LA,LB,LC,LD,LE	20I4	LA = number of variable angles in spine/right arm. LB = LA + number of variable angles in left arm. LC = LB + variable head angles. LD = LC + right leg angles. LE = LD + left leg angles.
6	(IDVAN(I),I=1,13)	20I4	Systems using varying angular limits, in the order: thorax(=1), neck(=2), clavicle(=3), shoulder, wrist, eye, hip, foot.
7	A(J-1), B(J-1), A(J), B(J)	4F10.1	Repeat cards 7 and 8 for I=1, ..., 8, with J=2*I. The angular limit values for Ø =0, 90, 180 and 270 degrees in the local system are read from card 7. Card 8 has corresponding "preferred" angles, which are not used in the RBA model.
8	PA(J-1), PB(J-1), PA(J), PB(J) (Actually, 16 cards are read)		
9	LJØIN,(IQ(L), L=1,LC), (IPAR(L), L=1,LC)	20I4	LJØIN = number of variable spine angles. IQ(L) = index in ISPRA, ILA, IH, IRL or ILL of the link to which angle L belongs. IPAR(L) = 1, 2, or 3, depending on which degree of freedom angle L represents. If IPAR(L) = 1, L is a θ (bend) angle. If IPAR(L) = 2, L is a ϕ (direction of bend) angle.

CARD	INPUT VARIABLE	FORMAT	DESCRIPTION
9			(Continued) If IPAR(L) = 3, L is a ψ (twist) angle.
10	(IQ(L),L=LC+1,LE), (IPAR(L),L=LC+1,LE)	20I4	The information corresponding to card 9 for the leg system Euler angle variables.
11	(ISPRA(I),I=1,IUB)	20I4	Spine/right arm system indices, beginning with bottom of spine.
12	(ILA(I),I=1,IUB)	20I4	Spine/left arm system indices.
13	(IH(I),I=1,NUB)	20I4	Spine/head system indices.
14	(IRL(I),I=1,MUB)	20I4	Right leg system indices.
15	(ILL(I),I=1,MUB)	20I4	Left leg system indices.
16	(CØNST(L),L=1,ICP)	8F10.0	ICP = ICØNST + 10. Several blank cards for the RBA model.
17	(CØN(K),K=1,ICØN)	8F10.0	ICØN = 3*NMJ - LE. These are values for Euler angles which remain fixed in systems having 1 or 2 of the possible 3 degrees of freedom. The order is: θ, ϕ, ψ, for the spine, right arm, left arm, head, right leg, and left leg.
18	MATRIX	I4	Set to zero (0).

CARD	INPUT VARIABLE	FORMAT	DESCRIPTION
19	(TRNSLT(ISPRA(I)), I = 1, IUB)	8F10.0	Spine/right arm link lengths.
20	THET,PHI,PSI Several cards possible.	3F10.0	Euler angle values for each fixed link in the spine/ right arm systems.
21	(TRNSLT(ILA(I)), I = IJØIN+1,IUB)	8F10.0	Left arm link lengths.
22	THET,PHI,PSI	3F10.0	Euler angles for fixed links.
23	(TRNSLT(IH(I)), I = IJØIN+1,NUB)	8F10.0	Head link lengths.
24	THET, PHI,PSI	3F10.0	Euler angles for fixed links.
25	(TRNSLT(IRL(I)), I = 1, MUB)	8F10.0	Right leg link lengths.
26	THET,PHI,PSI	3F10.0	Euler angles for fixed links.
27	(TRNSLT(ILL(I))), I = 1, MUB)	8F10.0	Left leg link lengths.
28	THET,PHI,PSI	3F10.0	Euler angles for fixed links.
29	(BL(L),BU(L),L=1,LE)	8F10.0	Fixed lower/upper limits for variable Euler angles (initial values).
30	(W(L),L=1,LE)	8F10.0	Initial values for all variable Euler angles.

CARD	INPUT VARIABLE	FORMAT	DESCRIPTION
31	(PTI(I),I=1,30)	8F10.0	For RBA, 4 blank cards.
32	MIMHP,MIMHØ,MIMLØS, MIMTØS,MIMFP,MIMFØ	20I4	For RBA, use the values 2, 0, 0, 0, 0, 0.
33	MFMHP,MFMHØ,MFMLØS, MFMTØS,MFMFP,MFMFØ	20I4	Same as card 32.
34	ERR,ERC,SCALE	8F10.0	Use the values .0001, .05, .50.
35	(PTF(I),I=1,30)	8F10.0	For RBA, 4 blank cards.
36	IRBASA	I4	Use zero (=0).
37	DELZ,ZERØ,DELTH,DIS, IA1,IA2,NLEV	4F10.0, 3I4	DELZ = spacing between reach planes (use negative value to start with top plane). ZERØ = height of initial reach plane (bottom of spine coordinates). DELTH = reach ray azimuth increment. DIS = value slightly outside reach capability (estimated) measured from vertical bar through bottom of spine. IA1,IA2 = initial and final reach rays. Ray 1 starts with azimuth = 0 degrees (to the right of the human operator). NLEV = number of horizontal reach planes.

APPENDIX F: COMPREHENSIVE ANNOTATED LIST OF MAIN PROGRAMS AND SUBROUTINES IN MMDLIB, WITH UPDATE DECK NAMES

MAIN PROGRAMS

PROGRAM	UPDATE DECK NAME	DESCRIPTION
ANPLØT	ANPLØT1	Outputs plot tape for link-system Euler angles at each motion step. Input link-system joints at each step. Deck includes subroutines MPLØT, START1.
ANPLØT	ANPLØT2	Different version - same description applies.
CØRPHI	CØRPHI	Converts HMA1 output by changing signs of some angles. Punch output.
HMA1	HMA1	Human subject motion analysis. Uses data from Phase II man-model validation. Input locations of certain arm/torso points (from tape-marks on motion picture frames of motion), calculate angles and link lengths at each motion step in accordance with a simplified spine/clavicle model.
MAN2	MAN2	The basic Phase II man-model main program, and from which the Phase II BGE Motion Model overlay and the Phase III Reach Basket Analysis program are derived. The MAN2 deck does not include the PRØGRAM header card. Two different versions of the PRØGRAM card are in decks MAN2PCH and MAN2PRG.
	MAN2PCH	PRØGRAM statement containing PUNCH in parameter list to get punched output from MAN2.
	ENM2PC	END card to follow MAN2PCH - included solely as a means of compiling all decks on the library in one compilation.
	MAN2PRG	PRØGRAM statement normally used with Phase II BGE or Phase III Reach Basket versions of MAN2.
	MANAPCH	PRØGRAM MAN2A statement for MAN2A (same as MAN3), the Phase II-A (Phase III) man-model with separate body system optimization. This PRØGRAM statement is for a version with punch card output.
	END2APC	END card to follow MANAPCH - included solely as a means of compiling all decks on the library in one compilation.
	MANAPRG	PRØGRAM statement normally used with Phase III BGE version of MAN2A (MAN2A has been renamed MAN3, but the UPDATE decks do not reflect this as yet).
MAN2A (MAN3)	MAN2A	The Phase III man-model main program. See MAN2 description for similar information relating to deck structure using different PRØGRAM call cards.

MAIN PROGRAMS

PROGRAM	UPDATE DECK NAME	DESCRIPTION
TNLPS	TANELPS	Main program of tangent planes package for body segment wrap-around planes. This package is mostly contained within deck TANELPS. It calculates vertices for circumscribing an ellipse with a polygon so as to minimize the difference between ellipse cross-sectional area and polygon cross-sectional area. The minimization presents a constrained minimization problem, and so a version of the LYNX package (deck LYNXLPL) is used along with the TANELPS package.
TLYNX	TLYNX	Test program for nonlinear constrained minimization subroutine LYNX. It calls LYNX with either of two objective function/penalty function subroutine packages. These are the FUN1-FUN1X/PEN1-PEN1X and the FUN2-FUN2X/PEN2-PEN2X packages. In this way, two different optimization problems can be run in a single computer run to test LYNX.
TRACE	TRACE	Provides a joint-trajectory analysis. Input vertices along a stepwise-determined trajectory. Data can be from either human subject motion or a man-model run on the computer.

SUBROUTINES

SUB-ROUTINE	UPDATE DECK NAME	DESCRIPTION
BADGER	BADGER	Unconstrained minimization using a stripped-down earlier version of LYNX. (The Numerical Analysis organization can supply more up-to-date codes for unconstrained minimization which should be more efficient and do use less storage.)
BEND	BEND	Solves for Euler angles θ and ϕ given 3 joint locations defining 2 adjacent links. Used in human subject motion analysis, among other things.
BØDNULL	BØDX	Dummy version.
BØDX	BØDX	BGE version (compatible with INTRAN link structure definitions). Entry points to (a) input body segment solids in local (body segment) coordinate systems, not scaled to size, and (b) rotate and translate local body segments into position using Euler angles and link lengths describing link-system position. Body segments are also scaled up to link-length size.
BØDXVAL	BØDX	Used with statistical validation (VAL) version of man-model. Does not actually supply body segments, but performs needed calculations for statistical validation.
BØXEAR	BØXEAR	Calculates vertices of a partition of a 3-dimensional rectangular box into cubes.
BS	BS	Called from entry points BØDZ and BØDW of BØDX to perform actual transformations to scale up and position the surface plane segments defining a solid body segment.
CØNVRT	CØNVRID	Identity transformation to replace CØNVRT when no angular constraints are being used.
CØNVRT	CØNVRT	Fixed (FJAL) or Discrete Variable (DVJAL) angular Limits version. Inverts the GMAP transformation to get free parameters from a given set of Euler angles with given lower and upper bounds.
CØNVRT	CØNVVJL	Version to invert the GMAP transformation to get free parameters from given Euler angles with given lower and upper bounds which vary continuously (VJAL version).
CRØSS	CRØSS	Three-space vector cross product. Supplies all relevant information, including vector norms, unit normal vector, and sine of included angle.

SUBROUTINES

SUB-ROUTINE	UPDATE DECK NAME	DESCRIPTION
CTERP	BADGER	Cubic interpolation subroutine for BADGER.
CTERP	CTERP	Cubic interpolation subroutine for LYNX.
CTERP	LYNXLPL	Cubic interpolation for Long Parameter List (LPL) version of LYNX.
ELIPSE	TANELPS	Part of TANELPS package.
EVALO	EVAABGE	Man-model environment subroutine for MAN3 BGE version. Certain statements (documented in code) must be removed before running as a BGE overlay, and calls to INJECT and RYTE should be removed or dummy versions of these two I/O routines supplied. The EVAABGE version as is will run MAN2A(MAN3) independently by calling for I/O and setting certain parameters, thereby taking the place of INTRAN and ØUTGØ of the BGE system.
EVALO	EVAAVAL	Man-model environment for MAN3 statistical validation.
EVALO	EVALBGE	Man-model environment for MAN2 in the BGE. However, see the EVAABGE description for important information. As is, this version will run MAN2 as an independent system with its own I/O.
EVALO	EVALRBA	Man-model environment for the MAN2 Reach Basket Analysis package.
FTERP	BADGER	Fibonacci interpolation for BADGER.
FTERP	FTEREXP	Fibonacci interpolation for experimental (EXP) version of LYNX.
FTERP	FTERP	Fibonacci interpolation for LYNX.
FTERP	LYNXLPL	Fibonacci interpolation for Long Parameter List (LBL) version of LYNX.
FUN1, FUN1X	NØRMXSQ	Test objective function for LYNX. Squared Euclidean norm of X.
FUN1, FUN1X	TANELPS	Objective function (cross-sectional area difference) for TANELPS package.
FUN2, FUN2X	ZERØ	Identically zero objective function for LYNX.

SUBROUTINES

SUB-ROUTINE	UPDATE DECK NAME	DESCRIPTION
GMAP	GMAP	Transforms optimization free-parameters to box-constrained Euler angles to remove the Euler angle box constraints from the LYNX optimization.
GMAP	GMAPID	Version of GMAP which is the identity (transforms angles to angles, straight across).
GMAP	GMAPVJL	Continuously varying Angular Limits (VJAL) version of GMAP.
HBAD	BADGER	Called by BADGER to operate on H matrix.
HID	HID	Sets N x N matrix to the identity.
HID	HIDCMP	CØMPASS version of HID.
INJECT	INJACT	Input subroutine for MAN3 BGE version when run <u>independently</u> of the BGE system.
INJECT	INJAVAL	Input subroutine for statistical validation (VAL) version of MAN3 package.
INJECT	INJECT	Input subroutine for MAN2 (any version) when run <u>independently</u> of the BGE system.
LEG, LEGX	LEG	Calculate constraint residuals for the leg systems during an optimization to solve for leg positioning Euler angles.
LIMP	LIMP	Sets up linear programming problem for spine system interpolation in MAN3 with separate body systems optimization.
LINE	LINE	One-dimensional linear interpolation between two points in N-space.
LINE	LINECMP	CØMPASS version of LINE.
LØS, LØSX	LØS	Calculate constraint residuals for line-of-sight viewing constraint during an optimization in which body positioning Euler angles are to be found.
LYNX	LYNXEXP	Experimental version of optimization subroutine LYNX.
LYNX	LYNXLPL	Long Parameter List version of optimization subroutine LYNX. It is much slower than LYNXVIP and its use is not recommended.

SUBROUTINES

SUB-ROUTINE	UPDATE DECK NAME	DESCRIPTION
LYNX	LYNXØLD	Prior version of optimization subroutine LYNX. Use is not recommended.
LYNX	LYNXVIP	Currently used version of optimization subroutine LYNX, which uses the Davidon Fletcher-Powell method with penalty function to minimize a differentiable nonlinear function of several variables, subject to nonlinear constraints on the variables. System routine VIP is called for inner products.
MAB	MAB	Multiply two matrices. Entry points for product of matrix times transpose of other matrix.
MAB	MABVIP	Version of MAB which calls system routine VIP for row-column products.
MAB, MABT, MATB	BADGER	In the BADGER version, the entry points to MAB are all separate subroutines, otherwise the code is the same as in the MAB deck.
MATINV	MATINV	Matrix inversion by Gaussian elimination with row pivoting. It is suggested that if a matrix inverse is ever needed, subroutine INVERS (on the EKS-MAINSTREAM subroutine library) be used. MATINV is not used in MMDLIB, and should be eliminated.
MPLØT	ANPLØT1, ANPLØT2	Called by program ANPLØT.
PARAM	PARAM	Called from output subroutine RYTE for formatted output of link-system Euler angles with associated information (lower and upper bounds, etc.).
PENLTY	PENLTY	Performs penalty function calculation for LYNX, with simple box constraints on the optimization variables (e.g., Euler angles).
PENLTY	PENLVJL	VJAL version of PENLTY.
PENLTY	PENLO.OO	Version of PENLTY for no box constraints on the optimization variables (e.g., in certain optimization test problems).
PEN1, PEN1X	SNMIN1	Constraint residuals and their gradients for optimization test problems with a sum-of-squares equality constraint.

SUBROUTINES

SUB-ROUTINE	UPDATE DECK NAME	DESCRIPTION
PEN2, PEN2X	PLANES	Constraint residuals and their gradients for optimization test problems with linear equality constraints.
PEN1, PEN1X	TANELPS	Constraint residuals and their gradients for calculating body segment cross-sections in TANELPS package.
PIVØT	PIVØT	Called by SYMBØL to perform pivoting.
PØC, PØCX	PØC	Constraint residuals and their gradients for optimization on arm or leg systems when MAN3 version is used for man-model.
PØC, PØCX	PØCEXP	Experimental version of PØC, PØCX.
PØCLØS, PØCLØX	PØCLEXP	Experimental version of PØCLØS, PØCLØX.
PØCLØS, PØCLØX	PØCLØS	Constraint residuals and their gradients for optimization on arm and head system in total or partial upper body positioning when MAN2 version is used for man-model.
PØCLØS, PØCLØX	PØCLRBA	RBA version of PØCLØS, PØCLØX.
PØSE	PØSA	Positioning link-system when Euler angles and link lengths are provided. PØSE provides the ability to position the man-model link-system whenever it is desired to do so without calling the optimization package. The PØSA deck is the MAN3 version.
PØSE	PØSE	The MAN2 version of PØSE.
PREFAN	PREFAN	Varies the "preferred" Euler angles in the objective function SPRING during an optimization in the VJAL version of the man-model. Can be used with either MAN2 or MAN3 versions.
PREFAN	PRENULL	Dummy version for use with fixed (FJAL) or discrete variable (DVJAL) versions.
PREP	PREP	Sets up VJAL storage for GMAP.

SUBROUTINES

SUB-ROUTINE	UPDATE DECK NAME	DESCRIPTION
RAKE	BADGER	BADGER version of RAKE.
RAKE	RAKE	Used by LYNX to call objective function and constraints during an optimization.
RAKE	RAKEVJL	VJAL version.
RAKE	RAKE000	NJAL version (no angular limits).
REDUCE	REDUCMP	Gaussian reduction for SYMBØL (CØMPASS).
REPLCE	BADGER	BADGER version of REPLCE.
REPLCE	REPLCE	Advances Davidon minimization progress in LYNX by storing current best solution.
REPLCE	REPLCMP	CØMPASS version.
RØT3	RØT3	Store 3 x 3 rotation matrix and its derivatives when Euler angle sines and cosines are input.
RØT3T	RØT3T	Transpose of RØT3 matrix is stored.
RØ3	RØ3	Stores 3 x 3 rotation matrix when Euler angles are input.
RP	RP	Accumulates product of rotations.
RYTE	RYTA	Man-model output routine for MAN3 version.
RYTE	RYTAVAL	Statistical validation (VAL) version of man-model output (MAN3 version).
RYTE	RYTE	Man-model output for MAN2 version.
SCALAR	SCALAR	Multiply vector times a scalar.
SCALAR	SCALCMP	CØMPASS version of SCALAR.
SPINE	SPINE	Spine interpolation main subroutine for MAN3 version.
SPINE	SPINRED	Simply reads and stores spine angles which are input. Used in statistical validation.
SPRING, SPRINX	SPRINGO	F(X) = 0 objective function and gradient. Calls GMAP to set up Euler angles even though F is 0.

SUBROUTINES

SUB-ROUTINE	UPDATE DECK NAME	DESCRIPTION
SPRING, SPRINX	SPRING1	Weighted sum-of-squares objective function and gradient. Weights and preferred angles are fixed during optimization (FJAL version).
SPRING, SPRINX	SPRING2	Same as SPRING1 version except some weights vary (the weight for each θ Euler angle depends on the associated ϕ Euler angle of a rotation triple (θ, ϕ, ψ) (FJAL version).
SPRING, SPRINX	SPRING7	Weighted sum-of-squares for VJAL version. The ϕ angle is not included as a separate term in the sum-of-squares.
SPRING, SPRINX	SPRING8	Same as SPRING1 deck but with a different storage scheme (DVJAL version).
SPRING, SPRINX	SPRIN10	Same as SPRING2 deck but with a different storage scheme (DVJAL version).
START1	ANPLØT1	Called by ANPLØT.
START1	ANPLØT2	ANPLØT2 version.
SYMBØL	SYMBØL	Linear programming subroutine for spine model. Also used by BGE overlays other than motion model.
TAN16	TANELPS	Part of TANELPS package.
TASK1	TASA	Body system/task execution sequencing logic for MAN3 version of motion model.
TASK1	TASK	Logic for MAN2 version of motion model.
TRAC	BADGER	BADGER version of TRAC.
TRAC	TRAC	Output subroutine for LYNX.
TRANSF	TRANØLD	Old version of TRANSF. Use not recommended (slow).
TRANSF	TRANVIP	Current best version of TRANSF. TRANSF is the true heart of the variable link-system model. The current set of Euler angles for the link system, together with the fixed link-lengths and the link-system tree structure logic, are used to calculate the positions of the link-system joints. TRANSF is called once for each branch of the tree, and accepts accumulated rotations/translations to connect the current branch with the branch to which it is attached.

SUBROUTINES

SUB-ROUTINE	UPDATE DECK NAME	DESCRIPTION
TWIST	TWIST	Finds the twist (ψ) angle given two joined links plus a point which rotates with and is external to one of the links.
VARBA	VARBA	Recalculates angular limits between optimizations for DVJAL version.
VARBA	VARNULL	Dummy version for use with other than DVJAL versions of motion model.
VTØX	LYNXLPL	Used in place of REPLCE in long parameter list (LPL) version of LYNX.
WRAP4	WRAP4	Sets up body segment solids to be stored and later rotated/translated into position along the link structure in scaled up form.
WRITBS	WRITBS	Optional output from body segments package (BØDX).
WWRAP	WWRAP	Optional output from BØDX following WRAP4 execution.

APPENDIX G: DMS/CGE INTERFACE MODULE SAMPLE PROBLEM

```
          COMPUTER AIDED FUNCTION-ALLOCATION EVALUATION SYSTEM

BEGIN CAFES=CREATE NEW DATA BANK/
    BEGIN DATA BANK EDITOR/
      CGEINPUT=A7E/
        COCKPIT PLANES=PLANES ONE AND TWO/
         NAME=PLANE1/
         NUMBER=1/
         VERTICES=1.0,1.0,1.0,2.0,2.0,2.0,2.0,1.C,0./
         NAME=PLANE2/
         NUMBER=2/
         VERTICES=0.,0.,2.0,0.,1.,1./
        CONTROLS=CONTROLS ONE AND TWO/
         CODE=CONTROL1/
         LOCATION=10.93,-2.62,0./
         EMBEDDED PLANE=3/
         BASE VERTEX=2/
         CODE=CONTROL2/
         LOCATION=10.93,-0.97,0./
         EMBEDDED PLANE=5/
         BASE VERTEX=3/
        EYE REFERENCE POINTS/
         LOCATION=1.0,2.0,3.3/
         NAME=PILOT/
        TASK SEQUENCES/
         SEQUENCE=SEQUENCE1/
         SEQPARM=A/
          TASK NUMBER=1/
          TASK DESCRIPTION=STANDARD POSITION/
          HAND CONTROL CODES=FCSTKRPAFT,FCCATG/
          EYE CONTROL CODE=FIADI/
          FOOT CONTROL CODES=RUDPDRANUT,RUDPDLANUT/
          HAND GRIP CODES=3,3/
          DURATION TIME=1.0/
          HOLDING TIME=1.0/
          EULER ANGLES=90.,90.,180.,90.,90.,90.,45.,90.,180.,90.,90.,-180./
         SEQUENCE=SEQUENCE2/
         SEQPARM=B/
          TASK NUMBER=1/
          TASK DESCRIPTION=MOVE LANDING/
          HAND CONTROL CODES=FCSTKRPAFT,FCLDGGRDWN/
          EYE CONTROL CODE=FILDGGRPOS/
          FOOT CONTROL CODES=RUDPDRANUT,RUDPDLANUT/
          HAND GRIP CODES=3,1/
          DURATION TIME=1.0/
          HOLDING TIME=1.0/
          EULER ANGLES=90.,90.,180.,120.,60.,-90.,45.,90.,180.,45.,90.,-180./
        CONTROL SHAPES=CONTROLS/
         NAME=MAIN INSTRUMENT PANEL/
         PLANE BOUNDARIES=1,5/
         NAME=LEFT HAND CONSOLE/
         PLANE BOUNDARIES=9,8/
       DUMP/
    END DATA BANK EDITOR/

 CATEGORY       2
```

```
           0
           0

6 RECORD        88
           3
           2
           0
           0
           0

6 RECORD        89
           2
           1
           0
           0
           0

6 RECORD        90
           1
         101
           0
           0
           0

8 END
    BEGIN PUNCHED OUTPUT/
     PUNCH=CGEDATA/
        CDDATA=LIST/
          EYE REFERENCE POINT=PILOT/
```

CDDATA PUNCHED OUTPUT

```
    1
   1.000    2.000    3.300
    1PILOT
 PLANES ONE AND TWO

   2
 PLANE1                                  1 3
    1.00     1.00     1.00     2.00    2.00     2.00     2.00     1.00      .00
 PLANE2                                  2 2
     .00      .00     2.00      .00    1.00     1.00
 CONTROLS ONE AND TWO

   2
 CONTROL1       10.930    -2.620       .000  3   2
 CONTROL2       10.930     -.970       .000  5   3
          CONTROL SHAPES=LIST/
```

CONTROL SHAPES DATA

```
TABLE NAME = CONSHAPA7E
CONTROLS


    2
MAIN INSTRUMENT PANEL                  1    5
LEFT HAND CONSOLE                      9    8
TABLE NAME =
          TASK SEQUENCES=LIST/
```

TASK SEQUENCE DATA

```
TABLE NAME = TASKSEQAA7
 1
  1       STANDARD POSITION
FCSTKRPAFTFCCATG    FIADI     RUDPDRANUTRUDPDLANUT3    3      1.000      1.000
   90   90  180   90   90   90   45   90  180   90   90 -180
TABLE NAME =
```

TASK SEQUENCE DATA

```
TABLE NAME = TASKSEQBA7
 1
  1       MOVE LANDING
FCSTKRPAFTFCLDGGRDWNFILDGGRPOSRUDPDRANUTRUDPDLANUT3    1      1.000      1.000
   90   90  180  120   60  -90   45   90  180   45   90 -180
TABLE NAME =
     END PUNCHED OUTPUT/
      BEGIN REPORT GENERATOR/
         REPORT=CGE DATA/
```

CGE COCKPIT PLANE DATA

CREW STATION NAME = A7E

COCKPIT PLANE DESCRIPTOR

PLANES ONE AND TWO

```
PLANE NAME    = PLANE1
PLANE NUMBER  =         1
VERTICES      =    1.0000    1.0000    1.0000    2.0000    2.0000    2.0
```

```
PLANE NAME    = PLANE2
PLANE NUMBER  =          2
VERTICES      =      .0000      .0000    2.0000      .0000    1.0000    1.000
```

CGE EYE REFERENCE POINT DATA

CREW STATION NAME = A7E

```
EYE REFERENCE POINT NAME = PILOT
LOCATION                 =      1.0000     2.0000     3.3000
```

CGE COCKPIT CONTROLS DATA

CREW STATION NAME = A7E

COCKPIT CONTROLS DESCRIPTOR

CONTROLS ONE AND TWO

```
CONTROL CODE        = CONTROL1
LOCATION            =     10.9300    -2.6200      .0000
EMBEDDED PLANE      =           3
BASE VERTEX         =           2

CONTROL CODE        = CONTROL2
LOCATION            =     10.9300     -.9700      .0000
EMBEDDED PLANE      =           5
BASE VERTEX         =           3
```

CGE TASK SEQUENCE DATA

CREW STATION NAME = A7E

COCKPIT TASK DESCRIPTOR

SEQUENCE1

TASK SEQUENCE NUMBER =A

TASK NUMBER	=	1		
TASK DESCRIPTION	=	STANDARD POSITION		
RIGHT HAND CONTROL CODE	=	FCSTKRPAFT		
LEFT HAND CONTROL CODE	=	FCCATG		
EYE CONTROL CODE	=	FIADI		
RIGHT FOOT CONTROL CODE	=	RUDPDRANUT		
LEFT FOOT CONTROL CODE	=	RUDPDLANUT		
RIGHT HAND GRIP CODE	=	3		
LEFT HAND GRIP CODE	=	3		
TASK DURATION TIME	=	1.0000		
HOLD TIME AT END OF TASK	=	1.0000		
RIGHT HAND EULER ANGLES	=	90.0000	90.0000	180.0000
LEFT HAND EULER ANGLES	=	90.0000	90.0000	90.0000
RIGHT FOOT EULER ANGLES	=	45.0000	90.0000	180.0000
LEFT FOOT EULER ANGLES	=	90.0000	90.0000	-180.0000

COCKPIT TASK DESCRIPTOR

SEQUENCE2

TASK SEQUENCE NUMBER =B

TASK NUMBER	=	1		
TASK DESCRIPTION	=	MOVE LANDING		
RIGHT HAND CONTROL CODE	=	FCSTKRPAFT		
LEFT HAND CONTROL CODE	=	FCLDGGRDWN		
EYE CONTROL CODE	=	FILDGGRPOS		
RIGHT FOOT CONTROL CODE	=	RUDPDRANUT		
LEFT FOOT CONTROL CODE	=	RUDPDLANUT		
RIGHT HAND GRIP CODE	=	3		
LEFT HAND GRIP CODE	=	1		
TASK DURATION TIME	=	1.0000		
HOLD TIME AT END OF TASK	=	1.0000		
RIGHT HAND EULER ANGLES	=	90.0000	90.0000	180.0000
LEFT HAND EULER ANGLES	=	120.0000	60.0000	-90.0000
RIGHT FOOT EULER ANGLES	=	45.0000	90.0000	180.0000
LEFT FOOT EULER ANGLES	=	45.0000	90.0000	-180.0000

```
                                                    COCKPIT CONTROL SHAPES DATA

                                              COCKPIT CONTROL SHAPES DESCRIPTOR

                    CONTROLS

                                                       CREW STATION NAME = A7E

          CONTROL SHAPES NAME     = MAIN INSTRUMENT PANEL
          UPPER PLANE BOUNDARY    =          1
          LOWER PLANE BOUNDARY    =          5


          CONTROL SHAPES NAME     = LEFT HAND CONSOLE
          UPPER PLANE BOUNDARY    =          9
          LOWER PLANE BOUNDARY    =          8


       END REPORT GENERATOR/
   END CAFES/
```

APPENDIX H: CAFES DOCUMENT INFORMATION GUIDE

AD-A033 856 BOEING AEROSPACE CO SEATTLE WASH F/G 9/2
COMPUTER AIDED FUNCTION-ALLOCATION EVALUATION SYSTEM (CAFES).(U)
MAR 76 R E EDWARDS, K S RENSHAW, M J HEALY N62269-75-C-0239
UNCLASSIFIED D180-19338-1 NL

3 OF 3
AD
A033856

END
DATE
FILMED
2-77

-C-

-C-

CAFES INDEX

-D-

-C-

CAFES INDEX

-F-

CAFES INDEX

-G-

-G-

CAFES INDEX

-H-

CAFES INDEX

-I-

CAFES INDEX

-M-

CAFES INDEX

-O-

-O-

CAFES INDEX

-P-

CAFES INDEX

-R-

CAFES INDEX

-S-

-S-

-T-

-U-

-W-

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER (14) D180-19338-1

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle) (6) COMPUTER AIDED FUNCTION-ALLOCATION EVALUATION SYSTEM, ~~PHASE V FINAL REPORT~~ (CAFES).

5. TYPE OF REPORT & PERIOD COVERED PHASE V FINAL REPORT 10 March 1975 through 10 March 1976

6. PERFORMING ORG. REPORT NUMBER D180-19338-1

7. AUTHOR(s) (10) Richard E. Edwards, Michael J. Healy, Kent S. Renshaw, Robert A. Atkins

8. CONTRACT OR GRANT NUMBER(s) (15) N62269-75-C-0239

9. PERFORMING ORGANIZATION NAME AND ADDRESS
BOEING AEROSPACE COMPANY
P. O. BOX 3999
SEATTLE, WASHINGTON 98124

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (12) 223 p.

11. CONTROLLING OFFICE NAME AND ADDRESS
NAVAL AIR SYSTEMS COMMAND (AIR 3034B)
WASHINGTON, D. C., 20360

12. REPORT DATE (11) ~~March 1976~~

13. NUMBER OF PAGES 220

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
TECHNICAL MONITOR
NAVAL AIR DEVELOPMENT CENTER
CREW SYSTEMS DEPARTMENT
WARMINSTER, PA, 18974

15. SECURITY CLASS. (of this report) Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N.A.

16. DISTRIBUTION STATEMENT (of this Report)

Distribution of this document is unlimited.

17. DISTRIBUTION STATEMENT ~~(of the abstract entered in Block 20, if different from Report)~~

(9) Final rept. 10 Mar 75-10 Mar 76 on Phase 5,

18. ~~SUPPLEMENTARY NOTES~~

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Computer Aided Design
Crewstation Geometry Evaluation
Crew Systems Design
Digital Simulation
Human Performance Modeling
Military Specifications and Standards
Panel Space Optimization
System Development

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report documents Phase V accomplishments in a continuing program to develop the Computer-Aided Function Allocation and Evaluation System (CAFES). CAFES is a crew systems design support system based on human engineering methods, computer aids, human performance data, and a data management system. It is intended to support crew systems engineers in systems development from initial mission and requirements analysis through design, test, training and maintenance systems development, as well as in the definition of man-machine research needs. Both the CAFES system and associated computer aids will be

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

dn

059 610

PRECEDING PAGE BLANK-NOT FILMED

20.

applicable to Human Factor activities in all the Navy systems.

The present report describes the CAFES developments that have transpired since the Phase IV Program. These developments included: (1) completion of the military specifications and standards data sets (MILSTAN) that are used for checking the compliance of crewstations against military specifications and standards applicable to two-place fixed-wing aircraft; (2) completion of a CAD/CGE Interface Module for the automatic transfer of crewstation geometry data from the Computer Aided Design Model to the Crewstation Geometry Evaluation Computer Program System; (3) an analysis of the current status and the development potential of the CGE Reach Basket Model; and (4) completion of a DMS/CGE Interface Module to provide for input, execution and output of Crewstation Geometry Evaluation data via the CAFES Data Management System. The Phase V document also includes a discussion of the preliminary design specification for a CONsole Space Optimization and Layout Evaluation (CONSOLE) Model, and the CAFES Phase VI program plan.